



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

CW
1060

WASHINGTON
GEOLOGICAL SURVEY.

BULLETIN No. 7

Gs - NA - W

HARVARD UNIVERSITY.



LIBRARY

TRANSFERRED

MUSEUM OF COMPARATIVE ZOOLOGY.

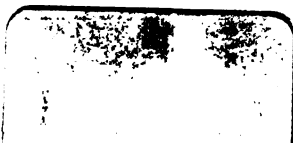
36299

5 1980

GIFT OF

TO GEOL. LIB.
Henry Land

March 4, 1912.



WASHINGTON GEOLOGICAL SURVEY

HENRY LANDES, State Geologist

BULLETIN No. 7

Geology and Ore Deposits of the Index Mining District

By CHARLES E. WEAVER



A OLYMPIA, WASH.:
E. L. BOARDMAN, PUBLIC PRINTER
1912

LETTER OF TRANSMITTAL.

Governor M. E. Hay, Chairman, and Members of the Board of Geological Survey:

GENTLEMEN—I have the honor to submit herewith a report entitled "Geology and Ore Deposits of the Index Mining District," by Charles E. Weaver, with the recommendation that it be printed as Bulletin No. 7 of the Survey reports.

Very respectfully,

HENRY LANDES,

State Geologist.

University Station, Seattle, December 1, 1911.

CONTENTS.

	<i>Page</i>
ILLUSTRATIONS	7
INTRODUCTION	9
Field work and acknowledgments.....	9
Location and area of the district.....	10
Industries and settlements.....	12
Literature	14
CHAPTER I. PHYSIOGRAPHY.....	21
Topography	21
General statement	21
Drainage	22
Forms of the surface.....	24
Glaciation	25
Climate	28
Vegetation	29
Relation of present topography to general geology.....	30
CHAPTER II. GENERAL GEOLOGY.....	34
General statement	34
Gunn Peak formation.....	35
Areal distribution	35
General description	36
Thickness	37
Correlation and age.....	37
Granodiorite	38
Areal distribution	38
Petrography	39
Contact relations	42
Granodiorite aplite	43
Andesite porphyry dikes.....	44
West Index andesitic series.....	44
Areal distribution	44
General description	45
Correlation	45
Howard arkose formation.....	46
General description	46
Areal distribution	46
Correlation	47
Olivine diabase	47
Quaternary	48
Glacial drift	48
Alluvial deposits	49
Talus deposits	49
Structure	49
Geological history	51

	<i>Page</i>
CHAPTER III. ECONOMIC GEOLOGY.....	54
History of mining.....	54
Treatment of the ores.....	56
Production	57
Distribution of the ore bodies.....	57
Character of the ore bodies.....	58
Strike	58
Pitch	59
Shape	59
Influence of the country rock on the ores.....	59
Alteration of the country rock.....	60
Mineralogy	62
Genesis of the ores.....	65
Placers	70
CHAPTER IV. DETAILED DESCRIPTION OF THE MINES.....	71
General statement	71
Sunset mine	71
Non-Parell mine	73
Ethel Consolidated mine.....	74
Kittanning mine	76
Merchant mine	77
Homestead mine	79
Co-operative mine	79
Lost Creek mine.....	80
Uncle Sam mine.....	81
Calumet mine	82
Florence-Rae mine	83
Bitter Creek mine.....	84
Index Bornite mine.....	84
Index Peacock mine.....	85
Gunn Peak mine.....	85
Helena mine	86
North Star mine.....	86
Index Independent mine.....	87
Buckeye mine	88
Copper Bell mine.....	90
Red Cross mine.....	92
Index granite quarry.....	92
Halford granite quarry	93

ILLUSTRATIONS.

<i>Plates</i>	<i>Opposite Page</i>
I. Outline map of a portion of Washington, showing the position of Index District.....	10
II. Geologic map of Index District.....	40
III. Horizontal plan showing mine workings of Ethel mine. Plan and cross-section B-B' of Non-Pareil mine.....	72
IV. Horizontal plan showing mine workings of the Bunker Hill mine	72
V. Cross-section A-A' of mine workings of Ethel mine. Cross-section G-G' of Bunker Hill mine. Horizontal plan of mine workings of North Star mine. Plan of mine workings of Merchant mine.....	80
VI. Horizontal plan and cross-sections E-E' and F-F' of the Sunset mine. Plan and cross-section C-C' of the Index Mining Company's mine. Horizontal plans of Index Bornite mine and Buckeye mine.....	80
VII. Map of mining claims of Index Mining District.....	88

INTRODUCTION.

FIELD WORK AND ACKNOWLEDGMENTS.

Geological field work in the Index Mining District was begun on August 2nd, 1910, and continued until September 20th of the same year. During this time the larger part of the areal geological mapping was completed, and many of the detailed underground examinations of the ore deposits were made. Later, during the autumn months of the same year, several shorter trips were undertaken for the purpose of completing the geological mapping and the examination of the individual mines.

Mr. Charles R. Fettke assisted in surveying the trails as well as many of the tunnels and open cuts. He also assisted in the areal geological mapping and in some of the underground studies. The ore samples taken from the various mining properties were assayed by Professor C. R. Corey, of the College of Mines of the University of Washington.

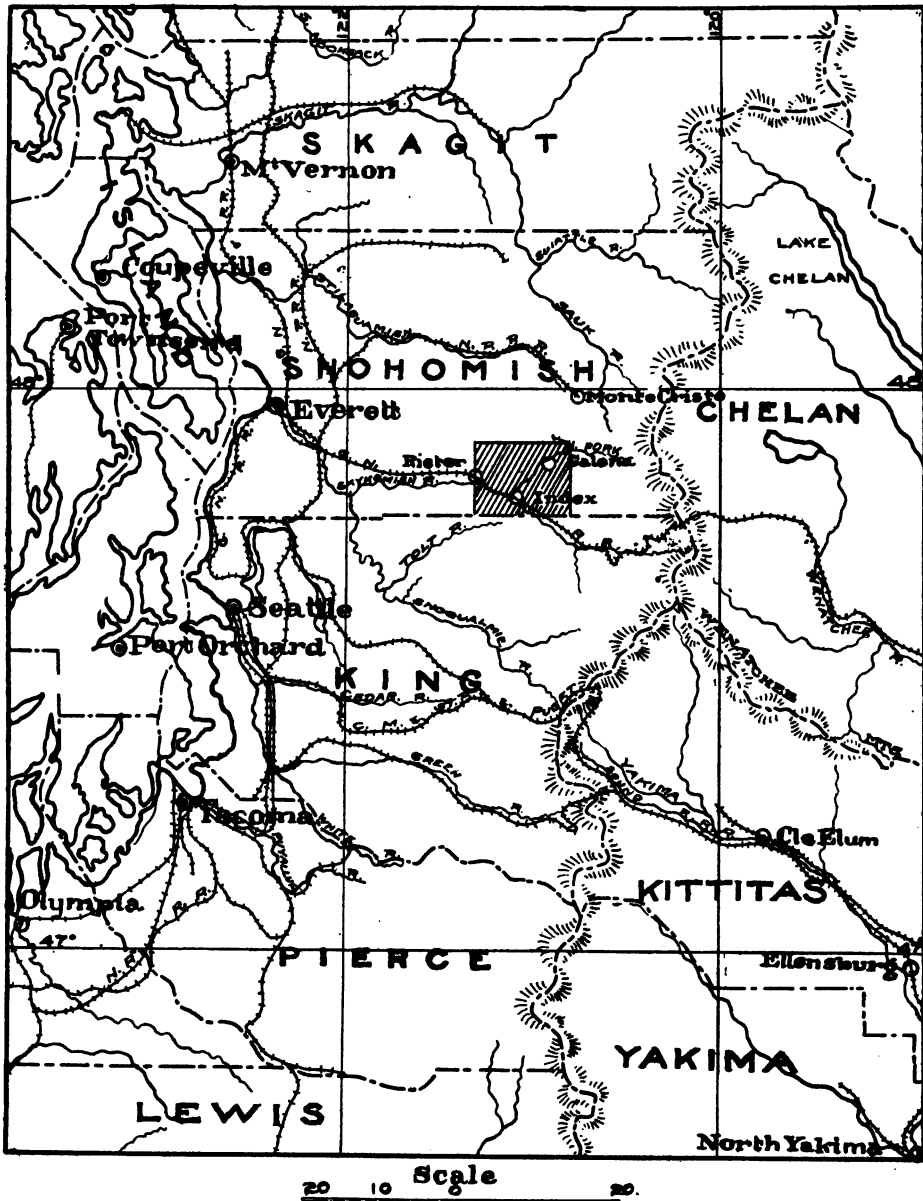
The topographic map which is used as a base for representing the areal distribution of the geological formations occurring within this district was in part constructed from a photographic enlargement of a portion of the Skykomish quadrangle, published by the U. S. Geological Survey, and in part from the Snoqualmie topographic atlas made by the Forest Service of the United States Department of Agriculture. The former was enlarged from a scale of one-half inch to the mile, to a scale of one inch to the mile, and the Forest Service map, which already existed on the scale of nearly one inch to the mile, with 200-foot contours, was made to conform to it. The

resulting map is on a scale of one inch to the mile with 100-foot contours. Wherever possible foot and compass surveys were made of the trails, and the cabins, mine openings and vein outcrops were tied in to some definitely located monument. Wherever mining maps, showing the plan of the underground workings, were not available, an attempt was made to construct them as accurately as possible by a tape and compass survey. On account of the extremely rough topography in parts of this district, it was impossible to actually traverse certain portions of the higher mountain crest lines and sharper pinnacles, but they were examined from every possible approach in order to determine their general character.

The writer wishes to express his thanks to the many mining men and prospectors, living or operating in this district, who have taken a deep interest in the progress of the investigation and who have given much personal assistance in carrying out this work in the field. Many of the smaller prospects and open cuts might have been overlooked if it had not been for their piloting the writer over the country. I wish to especially thank Mr. F. F. Otis, of the Non Pareil Mine, Mr. William Merchant, of the Merchant and Townsend property, and Mr. William Cornwall, of Index, for the facilities which they placed at the writer's disposal.

LOCATION AND AREA OF THE DISTRICT.

The Index Mining District is located in the southern part of Snohomish county, on the western side of the Cascade mountain divide, within the drainage area of the Puget Sound basin. Geographically it is situated in about latitude 47° and $50'$ north, and longitude 121° and $30'$ west, in the valley of the Skykomish, where the north and south forks of that river unite.



MAP OF PORTION OF CASCADE MOUNTAINS
SHOWING INDEX DISTRICT
WITH REFERENCE TO SURROUNDING COUNTRY.



Area Representing Index Mining District.
Areal Geology Mapped.

The Index District is an unorganized mining district and as such has no well defined areal limits. Locally, however, all of the mining claims in the vicinity of the town of Index, as far east as the towns of Galena and Baring are referred to as belonging to the Index District. All of the claims on Silver creek north of Galena are a part of the Silver Creek Mining District, and those still farther north belong to the Monte Cristo and Silverton Mining districts. In this report the area chosen for investigation consists of about 100 square miles, and in the west central portion of it is situated the town of Index. The south boundary of this district is represented by the King-Snohomish county line; the western boundary is a line extending north and south through a point two and one-fourth miles directly west of the junction of the north and south forks of the Skykomish river; the eastern boundary extends north and south from the junction of Troublesome creek with the north fork of the Skykomish river; the north boundary extends east and west through a point about one mile north of the town of Galena on Silver creek.

INDUSTRIES AND SETTLEMENTS.

Mining and lumbering are the principal industries of this district, and upon them nearly all of the others depend. With the exception of a few scattered homesteads along the river flats, there is very little arable land. Immediately west of this district the Skykomish river valley broadens and is dotted with many dairy and hay ranches. There is some logged-off land, which, when cleared, can be used for agricultural purposes. The slopes of the larger valleys, as well as the majority of the smaller ones entering into these, are heavily clothed with good, merchantable timber, which is now being cut and hauled to

the lumber mills situated along the line of the Great Northern railway. There is one large mill at Index and two more on the south fork of the Skykomish, between that town and Baring. Approximately 600 men are employed in this industry.

The mines and prospects are distributed over the entire district and are connected with the towns on the railroad lines by road, tram, or trail. Index is the largest settlement, with a population of 450, and is situated near the junction of the north and south forks of the Skykomish river. It is located on the main line of the Great Northern railway and is the chief distributing point for supplies in the district. Baring is the second town of importance, with a population of 200, situated on the Great Northern railway, nine miles east of Index, and is located on the south boundary of the map. Halford, also located on the Great Northern railway, is the third town of importance and owes its existence largely to the granite quarry immediately west of the town. Reiter is merely a stopping point on the Great Northern about five miles west of Index, with side track and water tank, and is connected with the Bunker Hill mine, about one mile to the north, by a surface tram road. Galena, an old settlement at the junction of Silver creek and the north fork of the Skykomish, was formerly a local base of supplies for the miners in that vicinity, but is now practically deserted. It is connected with Index by a good wagon road, nine miles in length and built along the north fork of the Skykomish river. From Galena a wagon road has also been built northward up Silver creek as far as the mining town of Mineral City.

In addition to these small settlements, many cabins may be found on the different creeks which are occupied by miners and homesteaders.

LITERATURE.

Very little has ever been written concerning the geology of the western portion of the Cascade mountains in the State of Washington. Only one geological folio has as yet been published, and that describes an area mainly within the drift-covered portion of the Puget Sound basin. No areal geological work has ever been done in the Index district and scattered references to the mines are very meagre. In the following list of publications, not only those papers directly referring to the Index district are given, but also those which describe and discuss the geology in other parts of the western Cascade mountains, and which seem to be closely related to the geology of this district. A short abstract with occasional quotations are given of those reports most closely related to the problems here involved:

HODGES, L. K. Mining in the Pacific Northwest, Index District, pp. 33-35, Silver Creek District, pp. 26-33. Published by the Post-Intelligencer, Seattle, Washington, 1897.

In this report a short description is given of each of the mining properties which had been located prior to the year 1897. The character of the ore, and its relation to the country rock is described. The geology of the district is characterized as "metamorphic granite diked with fine grained trap and a conglomerate overlaid with magnesium limestone. Cutting up into this are masses of diorite which in turn are later cut by a series of mineralized ledges having a north-west to south-east and a north to south direction." The Silver Creek district, which lies immediately to the northeast, is considered to be similar in character and to represent the southern extension of the Monte Cristo district.

RUSSELL, ISRAEL C. The Cascade Mountains in Northern Washington, 20th Annual Report, U. S. Geological Survey, Part II, pp. 82-210, 1898, Washington, D. C.

This paper presents the results of a geological reconnaissance made on both the east and west sides of the Cascade mountains. The area involved in the Index district was not visited, but an examination was made of the formations extending from the Cascade divide westward past Monte Cristo down the Sauk valley to Darrington, and also from this divide down the Skagit valley to Marblemount. Mr. Russell describes these formations as slates, schists, greenstones, granites, and overlying volcanic rocks, ranging in age from Paleozoic to late Tertiary, which had been much folded and contorted and then uplifted above sea level about 8,000 feet as an "elongated, nearly flat-topped dome, all the central part having the characteristic features of a plateau." He regards this as having been dissected by streams flowing both to the east and to the west and that the conditions on the west side were much more favorable for stream work than those on the east side, resulting in wider and much more dissected valleys. The general conditions involved in the glaciation of the west slope of the Cascades is discussed. Mr. Russell states, p. 172: "During the Glacial Epoch the Cascade mountains in northern Washington were heavily snow covered and gave origin to large glaciers of the alpine type. These flowed both east and west from the main divide, down previously deeply eroded stream valleys. The snow fields from which large trunk glaciers descended on the higher portions of the eastern slope of the mountains were confluent. On the west side of the main divide the snow fields were broader and thicker than on the east side—so thick, in fact, that when the glacial conditions were at their maximum a general ice sheet was formed which buried some of the most prominent ridges, es-

pecially in the northern portion of the region under consideration. It seems possible that along the northern portion of the Cascade divide in northern Washington, the snow was piled so high on the west side of the main divide that the snow divide was some distance west of the present rock divide." And on page 173, he states: "The westward-flowing glaciers drained a vast series of confluent snow fields, which, during times of maximum glaciation, formed a continuous ice sheet on all the higher portions of the western slope of the mountains. The trunk glaciers flowing from this ice sheet were, in general, broader and thicker than the similar glaciers on the east side of the range, and became true alpine glaciers of the character of the Seward glacier, Alaska, but expanded and united at their lower extremities and assisted in forming a large piedmont glacier which occupied Puget Sound basin. This piedmont glacier had two stages of broad expansion, separated by an interglacial stage, during which thick gravel deposits, together with layers of peat, were spread out on top of a basement layer of till." In this report no mention is made of the ore deposits in the Index district.

THYNG, WM. S. The Index District, pp. 114-120, 1st Ann. Rpt., Washington Geological Survey, Landis, Olympia, Wash., 1901.

In this report the more important mines are described, including the character of the ore and the amount of development work undertaken. Concerning the geology, he states the following: "The fundamental formation of the district is granite, which is in places crossed by dikes of trap, and at other points is overlaid with what appears to be slate, probably metamorphosed shale, and which is considerably altered and softened at the surface. Small amounts of impure lime-

stone are also found at certain points. So far as development has progressed, there appears to be but little uniformity in the trend or direction of the important ore bodies, but by far the greater part of the ledges appear to be fissure veins cutting the granite formation. The typical ores are chalcopyrite and bornite, the latter being generally found in greater proportions as depth is obtained." * * * "Gold is not usual * * * some veins have been discovered of what may be fairly considered as true gold ore, this gold ore is claimed to be free milling, although the properties have never been worked. Index is therefore to be properly considered, a copper mining district."

THYNG, WM. S. Silver Creek District, pp. 111-114, 1st Ann. Rpt. Wash. Geological Survey, Landes, Olympia, Wash., 1901.

This district is considered as the connecting link between the Monte Cristo district on the north and the Index district on the south. The country rock is described as being mainly granite and the ore in the upper part of the district principally copper and iron, carrying values in gold and silver. In the lower portion, just above the town of Galena, some silver-lead ore with subordinate amounts of copper pyrite carrying some gold are found.

The mines in this district are tributary to Index by means of a wagon road up the north fork of the Skykomish river, from Index to Galena and from there by another road up Silver creek. The geology of this district is described as follows, page 112: "The country rock of the district is mainly granite, less of the overlying sedimentary rocks being found than at Silverton to the north. The granite outcrops at a number of points along the entire length of Silver creek. The ore bodies

are mostly true fissure veins which have a general trend a little to the south of east. The ledges or veins are cut and faulted to some extent by probably a later series of fissure which appear to have a general direction or strike of northeast and southwest." A description of the underground workings and the character of the ore bodies is given for each of the important mining properties.

SPURR, JOSEPH E. Ore Deposits of Monte Cristo, Washington, 22nd Ann. Rpt., U. S. Geological Survey, 1900-01. Part II., pp., 777-888, Washington, D. C., 1901.

This paper presents the results of some detailed geological investigations made in the Monte Cristo Mining District in the State of Washington. The district is situated in Snohomish county, on the western slope of the Cascade mountains about 40 miles east from Everett and about 10 miles northeast of the town of Index. The results obtained here are of importance when considered in connection with the geology of the Index district, because of its proximity to Index and because it is the only detailed geological report on the western slope of the Cascades. An area of about 20 square miles was chosen and geologically mapped. The topography of this area is exceedingly rugged and with several fields of perpetual snow in the form of alpine glaciers occupying depressions on the high mountain crests.

The following geological divisions have been made in this district, p. 788:

- | | |
|--|-----------|
| 1. Ancient granitic rock, not exposed..... | Mesozoic |
| 2. Arkoses and conglomerates with some quartzites... | Eocene |
| 3. Earlier andesites and tuffs..... | } Miocene |
| 4. Tonalite (dacite) | |
| 5. Rhyolite | |
| 6. Basaltic rocks..... | |

7. Pyroxene-hornblende-andesites, tuffs and volcanic brecciasLate Pliocene-Pleistocene

Insomuch as the topographic and geological features and the processes of ore deposition of the Index and Monte Cristo districts are closely associated, it seems desirable to state Mr. Spurr's ideas concerning the latter district. The following statement is quoted from his summary on pp. 863-864:

"The rock series of the Monte Cristo district has at its base a hypothetical granite, not actually determined, although recognized in other neighboring districts. The lowest actually determined formation seems to be a series of heavy arkoses. These are capped by thick andesitic tuffs and flows, and these by thick basalts, with a sparing amount of rhyolite, which is probably intermediate in age between the andesites and the basalts in general. The basalts are overlain by later andesites which constitute the youngest of the rocks. Probably between periods of the early andesites and the basalts came intrusions of tonalite, which by contact metamorphism transformed narrow zones of the intruded rock into silicified phases and schists.

"These rock formations are all Tertiary, ranging from Eocene to late Pliocene or early Pleistocene. In late Tertiary times the rocks (with the exception of the later andesite, which was not yet poured out) were folded and subsequently planed down by erosion. Then in late Pliocene or early Pleistocene time came an uplift of the planed surface to form a plateau. This uplift was accompanied by the extrusion of the later andesite and by fracturing. Immediately after the inception of the uplift, the dissection of the present topography began, and with it the deposition of the ores.

"These ores have formed chiefly along the joints and fractures, and are often especially localized at the intersection of different fractures. The areas of most profound fracturing are in general the areas of greatest mineralization. The ores

are especially abundant in the tonalite; to a less extent in the andesite.

"In the observed veins of the district it is found that the ores are most abundant near the surface. There is a rough succession from the surface downward, of galena, blende, chalcopyrite, pyrite, and arsenopyrite. The upper zones characterized by galena, blende, and chalcopyrite, contain more gold and silver than the lower zones, characterized by pyrite and arsenopyrite.

"Upon various grounds it has been concluded that the upper sulphide zone, which contains the most and the richest ore, was deposited, largely at least, since the development of approximately the present topography, by downward-trending waters. Lead, one of the most conspicuous metals of this zone, is not known to be present in the lowest ores, and so is not regarded as having been derived by the concentration of ores like those in the lowest zones; but is, perhaps, as the known facts indicate, an original deposit by descending waters. This theory involves the derivation of the lead ores, from the surrounding rock. The lower sulphide zones afford less evidence as to their origin, but what there is tends into the same direction as that for the upper zones, so that the general suggestion is deduced that all the zones were precipitated, in part simultaneously, by downward percolating waters, the different belts of minerals being precipitated in order according to their relative solubility. Similar phenomena in other regions, and the known chemistry of such phenomena, support these deductions from independent local evidence."

GEOLOGY AND ORE DEPOSITS OF THE INDEX MINING DISTRICT.

CHAPTER I. PHYSIOGRAPHY.

TOPOGRAPHY.

GENERAL STATEMENT.—The topography of the Index Mining District, in common with that of the western slope of the Cascade mountains, is extremely bold and rugged. The central portion of the range extending from the Snoqualmie river on the west to the Columbia on the east—a distance of about seventy-five miles, comprising Chelan, Snohomish and King counties, presents a broad elevated mountain mass deeply dissected by several large valleys. These extend eastward to the Columbia river and westward to Puget Sound and head at intervals along a north-south line which represents the Cascade divide and lies a little to the west of the center of the range. At the present time this elevated mountain mass has a maximum elevation ranging from 6,000 to 8,000 feet along the main divide, with a gradual decrease eastward to the Columbia river, where the elevation is 1,000 feet, and a more rapid decrease to the westward to sea level. Observations made from some of the higher peaks on the western slope of the mountains show the summits of the crest lines between the larger stream valleys to accord in level with a gradual slope to the west.

The large trunk streams heading near the divide and flowing westward are the Snoqualmie, Skykomish, Stillaguamish and Skagit. Those flowing to the east are the Wenatchee and Yakima. The Index district lies about fifteen miles west of the main divide and entirely within the drainage basin of the Sky-

komish river. This river, including the north and south forks, together with numerous smaller tributary streams, has deeply dissected the area, leaving deep valleys with steep slopes, and high ridges with saw-tooth crests which are often inaccessible. High up in these divides, especially near the sources of the larger creeks, are glacial cirques, generally containing small, rock-rimmed lakes, surrounded with talus slopes. One of the most prominent topographic features of the Index district is a high, mountainous mass, lying between the north and south forks of the Skykomish river and culminating in Gunn peak and Mount Index. To the south of the town of Index, on the south side of the Skykomish river, are west Mt. Index and Mt. Persis, which project as pinnacles from the crest of the ridge between the Skykomish and Tolt river valleys.

DRAINAGE.—The drainage of the western slope of the Cascade mountains in the State of Washington is accomplished through several large river valleys, with their numerous branches, which head near the crest of the range and find their outlet through Puget Sound and the lower portion of the Columbia river. The largest of these streams, beginning at the north in Whatcom county, are the Nooksack, Skagit, Stillaguamish, Skykomish, Snoqualmie, Cedar, Green, White and Nisqually rivers, all of which drain to Puget Sound. Farther south are the Cowlitz and Lewis rivers, which find their way to the Columbia.

All of these river valleys are characterized by narrow canyons with extremely high grades and numerous waterfalls in their upper courses, by broader valleys with medium grades along their middle stretches, and by broad alluvial plains near the Sound.

The drainage within the Index district proper is almost entirely through the north and south forks of the Skykomish river. An extremely small area in the southwestern portion of the district is within the drainage basin of the Tolt river. The north and south forks of the Skykomish river join about one mile west of Index, forming the Skykomish river proper. Drain-

ing into this from the north and west of Index are Deer, Hogarty, May and Wallace creeks. The area to the south of the Skykomish is drained chiefly by Proctor creek, which finds its way into the Skykomish river about three miles to the west of the limits of the map. The area to the north of the north fork of the Skykomish river is drained by Silver creek, which empties into the north fork of the Skykomish at the town of Galena and by Salmon, Excelsior, Curry and North Star creeks. The area between the north and south forks of the Skykomish is drained by a number of creeks flowing northward and others flowing southward, separated by a group of high, rugged mountain peaks—represented within this district by the Gunn peak and Mt. Index mountain mass. The most important of those creeks flowing northward are Howard, Bitter, Canyon and Lewis creeks. Of those flowing southward, Barclay creek is the most prominent. The area on the south of the Skykomish is drained by three northward flowing creeks, namely: Anderson creek, Bridal Veil creek and Philadelphia creek.

The elevation on the north fork of the Skykomish river in the northeast corner of the district is 1,300 feet. This gradually decreases for a distance of 12 miles, where at the town of Index, it is 528 feet. On the south fork of the Skykomish, near the southern boundary of the map, at the town of Baring, the elevation is 759 feet, which in a distance of eight miles, at the junction of the north and south forks of the Skykomish, drops 230 feet.

An area of about twelve square miles in the eastern part of the district is drained by Trout creek, which empties into the north fork of the Skykomish river, about midway between Index and Galena. This creek is about eight miles in length and carries a considerable volume of water throughout the year. On the north and east side of this valley, is a high, rugged ridge forming Iron mountain. About five miles from the junction of the north fork of the Skykomish with Trout creek, the latter divides into a north and south branch, each of which is partially fed by a small, rock-rimmed lake, situated in an amphi-

theater of glacial origin at its head. The water from these lakes is drained through narrow outlets and tumbles down the slopes of the valleys in a series of cascades.

On the east side of Iron mountain is located Howard creek, draining an area of about nine square miles and occupying a deep canyon between Iron and Spire mountains. This stream rises in Howard lake at an elevation of about 4,000 feet, and flows northeasterly for a distance of five miles, where it joins the north fork of the Skykomish about one mile below Galena, at an elevation of 1,050 feet.

Bitter creek, lying to the south of Trout creek, and approximately parallel to it, drains an area of four square miles, and empties into the north fork. Barclay creek, still farther south, rises in a small glacial lake, on the north side of Mt. Index, drains an area of about eight square miles and empties into the south fork of the Skykomish about one mile west of the town of Baring. This creek is about seven miles long and decreases gradually from an elevation of 3,500 feet at its head to 800 feet at its mouth.

All of these streams contain more or less water throughout the entire year, and many of them during the winter freshets become raging torrents, and as such are a very active factor in erosion. On account of the great volume and the precipitous courses of these streams, much power is available for economic uses.

FORMS OF THE SURFACE.—The maximum elevation attained within this district is on Gunn peak, 6,245 feet. This is situated in the southwestern portion of the area, and constitutes the highest part of an extremely rugged, mountainous mass, forming the water shed between the north and south forks of the Skykomish river. To the south of Gunn peak, on the southern border of the district, is Mt. Index, with an elevation of 6,125 feet and separated from the Gunn peak mass by the deep valley carved out by Barclay creek. To the east of Gunn peak mass, lies a steep, bold series of mountain ridges, ranging in elevation from 5,200 to 6,000 feet and separated from it by

the deep, erosional valley of Trout creek. The higher peaks in this elevated region consist of Merchant peak, 5,465 feet; Conglomerate point, 5,320 feet; Iron mountain, 5,241 feet; and Spire mountain, 6,065 feet. Still farther east, beyond the limits of this district, this mountainous area gradually increases in elevation to an average of 7,000 feet, near the Cascade divide. In a westerly direction it decreases to an elevation of about 800 feet along the north fork of the Skykomish river. Northwest from the north fork of the Skykomish river, the elevation rapidly increases about 3,000 feet in two miles, resulting in a long, northeast to southwest ridge whose crest line is a part of an elevated plane which increases in elevation to the north about 100 feet to the mile. Parallel to the long ridge just mentioned are two others in the northwest portion of the district, whose elevated crest lines can be accounted for as remnants of this elevated, northward sloping plane. The parallelism of these ridges may be accounted for by the general northeast southwest trend of Hogarty and Wallace creeks, which have carved out deep canyons into this plane, leaving between them sharp divides.

In the southwestern portion of the district is a steep mountain mass rising from the south fork of the Skykomish river at an elevation of 500 feet to 4,000 feet in a distance of one and three-fourths miles. This mass forms the divide between the drainage basin of the Skykomish river on the north and that of the Tolt river on the south. That portion of the crest line occurring in this district is situated on the extreme southwestern border extending nearly east and west and reaching a maximum elevation of 4,600 feet in the high spire of Mt. West Index. This mountainous area is cut up into steep, elongated spurs by several northward flowing creeks which find their way to the Skykomish river.

GLACIATION.

Glaciers have played a very important part in the physiography of the Cascade mountains. On both the eastern and western slopes pronounced evidences of extensive glaciation

may be seen in all of the river valleys from the crest of the divide to Columbia river and Puget Sound. Glaciers developed in both the northern and southern portions of the range, but were much more extensive in the former.

Many small alpine glaciers are still in existence on the flanks of the higher peaks and ridges and on the slopes of some of the lofty volcanic cones. But the most important ones developed during Pleistocene time and were contemporaneous with at least a part of the great Continental glaciers which covered so large a part of the northern portion of the North American continent.

The facts as observed to the west of the Cascades in the Puget Sound region indicate two distinct periods of glaciation separated by an interglacial period during which the earlier ice streams had retreated far up into the main trunk valleys leading down from the crest of the Cascades. The evidence is the superposition of two different glacial deposits along the western foothills of the range. The ideas held concerning the glaciation of the Puget Sound basin are that as the glacial period gradually advanced, glaciers began to develop in the higher altitudes near the summit of the range and as they increased in size, flowed both to the east and west through the erosional valleys as long streams of ice. Ultimately those on the west reached Puget Sound and coalesced, and together with the great tongues of ice coming southward through the straits of Rosario from British Columbia, united to form a broad belt of ice occupying nearly all of the Puget Sound basin from the Cascades to the Olympic mountains. These westward flowing streams of ice seem to have gradually increased in volume and to have filled all of the smaller valleys and in many cases to have covered over the divides between them. The evidence for this may be found in the occurrence of glacial drift not only on the slopes of the valleys but also on the crests of the mountains separating them.

Finally as the climate became warmer and the ice streams began to retreat, thick deposits of rock debris were left behind

in the trail of the glacial stream as moraines. As the ice finally disappeared the heads of the larger valleys and some of the smaller ones leading to them were marked by many small, rock-rimmed lakes situated in cirques or glacial amphitheaters which originally were the gathering grounds for the large ice streams. Prior to the advent of the glaciers, valleys due largely to stream erosion and characterized by steep V-shaped canyons drained the country from the Cascade divide westward. During glaciation the large ice streams modified the pre-glacial valleys by scouring and rounding their slopes and developing the characteristic U-shaped valleys. The present condition of the topography is largely due to this process.

The area involved in the Index district, which is situated well up in the Cascade mountains, has been extensively glaciated in common with the western slope of the range. Two large glaciers flowed down the north and south forks of the Skykomish river and joined in the vicinity of the town of Index. From there they traveled westward as one ice stream through the Skykomish valley to Puget Sound. At intervals along their course, the two ice streams just mentioned received lateral feeders, several of which had their gathering ground within the area of this district. Two rock-rimmed basins or cirques now occupied by lakes, occur at the heads of the north and south forks of Trout creek. Each of these, in common with a majority of the others to be mentioned, are surrounded by steep talus slopes. The slopes of the valley of Trout creek, to an elevation of 1,000 feet above the creek bed, are covered with glacial drift. At the head of Howard and Barclay creeks glacial cirques occur and the valleys leading from them show the same pronounced effect of glaciation. Salmon, Wallace and Hogarty creeks also represent pre-glacial stream valleys which have been rounded and scoured by small ice streams leading down to the main Skykomish valley glaciers. Along the slopes of the Skykomish valley evidences of glacial drift may be seen up to an elevation of 1,000 feet above the river bottom. To the west of the town of Index, the glacial material

assumes a considerable thickness and through this the Skykomish river has re-excavated its channel to its present position.

CLIMATE.

The climate of the Index district presents a wide range of variation. The annual rainfall in common with that of the western slope of the Cascades, is heavy. In the more highly elevated portions of the district, the precipitation is much higher than at the town of Index and during the winter months a considerable portion of it is in the form of snow. The following table compiled from the United States weather reports* gives the monthly and annual precipitation for Index and Monte Cristo:

MONTE CRISTO.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895			9.39	9.60	11.74	2.24	2.20	0.71	11.45	1.70	10.92	23.14	.....
1896	16.43	15.36	8.71	6.43	5.90	5.12	T	1.29	2.75	5.85	17.50	.....	.....
1899		15.07	8.40	10.87	8.08	5.38	.....	.....	3.40	10.21	25.26	15.07	.....
1900	13.80	15.23	13.24	4.96	13.62	10.92	2.84	.....	.....	.....	.....	.....	.....
1901		16.09	10.40	9.45	4.71	8.33	1.97	0.17	6.27	8.43	.....	.....	.....
Mns.	15.12	15.44	10.08	8.26	8.78	6.40	1.75	0.72	5.97	6.55	17.99	21.60	118.51

The data given for Monte Cristo is representative of the high mountainous region about Trout, Howard and Barclay creeks, while that given for Index applies to the town and valley of the Skykomish.

INDEX.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1894										10.33	16.61	8.84	.....
1895	13.91	8.36	8.40										.....
1904					2.45	5.26	2.55	0.54	1.69	5.10	25.65	15.37	.....
1905	10.94	9.23	11.64	3.79	6.80	4.44	1.10	4.02	6.02	.....	.....	.....	.....
Mns.	12.42	8.82	10.02	3.79	4.02	4.84	1.82	2.28	3.86	7.72	21.13	12.10	98.42

The temperature varies in different parts of the district. In the eastern portion it is somewhat cooler than at the town of

*U. S. Department of Agriculture, Weather Bureau, Summary of the Climatological Data for Western Washington, Section 19, by G. N. Salisbury.

Index and even there it is only slightly colder than at Everett or Seattle. No records are available for the town of Index. For Monte Cristo the mean temperature throughout the year is as follows:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
38.6	31.9	36.6	40.9	45.9	52.8	61.0	68.0	58.8	50.8	38.4	35.6	45.4

In the high mountain areas snow begins falling in October and does not disappear until late in May and in the more favored and elevated spots where the sun does not have free access, it often remains throughout the entire year. On the highest mountain ridges snow flurries may occur even during July and August. In the valley of the Skykomish where the elevation ranges from 350 to 500 feet, only occasionally does snow fall and then it rapidly disappears.

VEGETATION.

A large part of this district, up to an elevation of 3,000 feet, is heavily covered with a thick growth of timber consisting largely of red fir, white fir, and red cedar. In the zone ranging from 3,000 to 5,000 feet the timber is neither so large nor thick, the trees most common being white pine, noble and lovely fir, Engelmann spruce, tamarack, Alaska cedar, Merten's hemlock, and yew. Above the 5,000 feet elevation zone the trees are small, often scrubby, and of a sub-alpine character, chiefly the sub-alpine fir and Patton's hemlock. Because of the great amount of moisture, the valley bottoms and mountain slopes support a luxuriant growth of ferns, mosses and devil's club. Those areas which have been burned over or logged-off support a thick undergrowth of salmon berry, blackberry, raspberry and huckleberry bushes, together with vine maple, rendering travel almost impossible. Much of the timber along the north and south forks of the Skykomish is now being cut and prepared for the market at the mills situated along the line of the Great Northern Railway.

RELATION OF THE PRESENT TOPOGRAPHY TO THE GENERAL GEOLOGY.

The present topography of the Index district has been produced by the same causes which have developed that of the western portion of the central Cascades. Insomuch as very little investigative work has been undertaken in the western part of the Cascade mountains, our knowledge of its physiography is very limited. The ideas set forth in this discussion are the interpretation of the facts gathered within the district considered, in connection with previous studies made to the north in the Stillaguamish valley and to the south in the Snoqualmie valley, together with published information concerning the physiography and structural movements on the eastern side of the Cascade mountains.

The factors which have been most important in developing the topography on the west slope of the mountains are a series of uplifts accompanied by folding, peneplanation, and warping of the mountain mass, the consequent adjustment of streams to structure, and the final modification of the stream valleys by glaciation and subsequent erosion. Observations taken from several of the higher peaks within the Index district between the valleys of the Sauk to the north and that of the Skykomish to the south show many ridges and peaks conforming in altitude and lying in a plane whose general slope gradually decreases to the south towards the valley of the Skykomish. To the north there is a much steeper descent to the valley of the Sauk and Skagit. The suggestion at once arises that this region represents an uplifted peneplain, characterized by a long southeast to northwest axial warp, which has been deeply dissected by stream erosion. The axis of this warped structure is seen in a prominent divide, beginning at the summit of the Cascades near Cady pass at an elevation of about 4,400 feet and extending northwesterly through Columbia peak and the high mountains north of Monte Cristo out toward the Sound, where it seems to continue as a prominent topographic feature into the San Juan island group and on beyond to Vancouver Island.

The western portion of this spur of the Cascades is extremely complex and has been subjected to other deformational movements which were perhaps even more influential in shaping the topography than those which formed the spur further to the east. For the sake of reference, this spur will be called the Skykomish mountain uplift. One of the characteristic features of this uplift is the length and distribution of the lateral drainage lines. Those on the north side are short, with steep grades, and flow straight down to the Sauk, while those on the south are three or four times as long, with much lower grades and broader valleys. It is also worthy of mention that the high mountain ridge to the south of the Skykomish river, which forms the divide between that river and the Snoqualmie, is similar in character, having short streams with high grades draining northward directly to the Skykomish river, and longer streams with lower grades draining southward to the Snoqualmie river.

Investigations made by Russell,* Willis† and Smith‡ on the eastern slope of the Cascade mountains have accounted for the origin of that long spur of the Cascades which forms the divide between the Yakima and Wenatchee valleys, known as the Wenatchee mountains. This extends from the Columbia river northwesterly through Mt. Stewart to the Cascade divide. They attribute it to a deformational uplift of that portion of the mountains resulting in a long southeast northwest axial warp. The continuation of this Wenatchee uplift northwesterly across the summit becomes a part of the Skykomish mountain uplift.

The explanation given to account for the topography on the western side of the Cascades in the region near Index, is only tentative and future detailed investigations in the central and northern portions of the western Cascades will probably revise,

*Cascade Mts. in Northern Washington. 20 Annual Rpt. U. S. Geol. Survey, Part 2, pp. 140-145. 1899.

†Contributions to the Geology of Washington. Professional paper No. 19, page 91. 1903.

‡Mount Stuart Geological Folio, pp. 2 and 3.

if not altogether change these ideas. Proceeding on the hypothesis just outlined, the topography of this district is a part of the southern slope of the Skykomish mountain uplift. The north fork of the Skykomish river, Silver creek, Hogarty and Wallace creeks, are all southward flowing streams draining the more elevated areas to the north. Sufficient facts have not been obtained to warrant a discussion of the early Tertiary structural movements which have affected this region. From evidence already stated, it is assumed that during late Tertiary times the region was reduced to a peneplain and then perhaps during late Pliocene or early Quaternary, uplifted to an elevation of more than 7,000 feet above sea level and subjected to differential deformation, resulting in a long axial warp extending in a northwesterly direction between the present position of the Skykomish and the Sauk rivers, from the Cascade summit to the Puget Sound basin. This uplift is considered to have been contemporaneous with and to have been produced by the same causes which produced the Wenatchee uplift on the eastern side of the Cascades. It is possible, although not certain, that northwest southeast faulting accompanied this uplift, resulting in a series of tilted fault blocks, accounting for the rather steep escarpment on the north side of the ridge toward the valley of the Sauk, and the more gentle slope towards the valley of the Skykomish and the repetition of this is in the divide between the Skykomish and Snoqualmie.

During the progress of the uplift of the Skykomish mountain mass, drainage lines began to develop both to the north and south, giving rise to the present valleys of the Sauk and the Skykomish. Lateral streams soon developed and carved out canyons, the longer ones extending to the Skykomish and the shorter ones leading down directly to the Sauk river. Farther to the west other structural movements were also involved, making the process of topographic development more complex and difficult of explanation with the information which we have at present.

The topography produced as the result of deformation and

consequent stream erosion was still further modified by glacial erosion and deposition. Great streams of ice moved down the stream erosional valleys, scouring their bottoms and rounding their slopes, and removing a tremendous amount of rock debris, which was carried down toward the Sound and finally dropped as the glaciers began to retreat, forming a thick deposit of glacial drift. As these ice streams finally moved back up the valleys from which they came, they left them partly filled with unassorted gravel, sand and clay and overlain with stratified gravels and sand deposited by streams issuing from the margins of the glaciers. Post-Glacial stream erosion has re-excavated these channels, which may be well seen near the junction of the north and south forks of the Skykomish river, west of the town of Index.

As the result of glaciation the headwaters of many of the streams high up in the mountains are characterized by glacial amphitheaters, many of which contain small glacial lakes with small outlets, having the relation of hanging valleys to the larger creeks into which they empty. The slopes of these larger creeks are covered with glacial drift for more than a thousand feet above the creek beds.

CHAPTER II.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The geological formations involved in the Index district comprise igneous, metamorphic, and sedimentary rocks, including glacial drift. These occur in the Cascade mountains both to the north, south and east of this district. They have never been described, with the exception of the granodiorite, which, in a general way, has been referred to by I. C. Russell as granite.*

The determination of the geological age of the formations occurring in the Index district will, of necessity, be largely based upon our knowledge of similar formations occurring to the north in the Monte Cristo district, and to the east in the Snoqualmie and Mount Stuart regions where more detailed studies have been made. The oldest rocks are a thick series of metamorphosed sediments composed of quartzites, slates, crystalline limestone, cherts and schists, together with interbedded igneous flows. These rocks have been extensively metamorphosed and the subsequent movements to which they have been subjected have rendered it almost impossible to work out any definite structure or to subdivide the series upon a stratigraphical basis. This formation will be designated in this report as the Gunn peak formation, because of its typical development in that region, and its age seems to be most certainly Pre-Cretaceous. The next younger formation is a part of a great batholith of granodiorite which underlies a large part of the Cascade mountains and which also is represented in British Columbia and further to the south in Oregon and California. It resembles very closely the Mount Stuart granodiorite on

*Twentieth Annual Report, Pt. II., p. 107, U. S. Geological Survey, Washington, D. C., 1899.

the eastern side of the Cascade mountains, but in this report will be designated as the Index granodiorite. Following the intrusion of this plutonic mass into the earth's crust, there was a long period of erosion, during which time a large part of the overlying sediments were removed by stream action. During early Eocene this region was subjected to mountain making movements which resulted in the formation of extensive lake basins and the sediments accumulating in them within this district are represented by a series of granitic arkose and intercalated lava flows. After the deposition of the arkose series, this region was intruded by a series of basic dikes, and following the intrusion of these came outflows of andesitic lavas and tuffs. At some time late in the Pliocene or perhaps in early Pleistocene, the Cascade mountains were uplifted and stream erosion began its work of carving out the valleys, among which within this district are the north and south forks of the Skykomish. Later, during Pleistocene time, great valley glaciers began their advance down towards Puget Sound, removing as they went great volumes of rock from the mountain areas. This material now forms a thick veneer over the older rock formation and constitutes the glacial drift.

GUNN PEAK FORMATION.

AREAL DISTRIBUTION.—This formation is widely distributed in the southeastern part of the district, where it covers an area of approximately sixteen square miles. Beginning in the northeast corner it forms a belt about one and one-half miles in width, one-half lying on either side of Silver creek above the junction of that creek with the north fork of the Skykomish, at the town of Galena. This belt extends in a southerly direction and the western boundary lies about one-half mile west of Lost creek. From here it passes along the western side of Iron mountain and extends along the eastern side of Trout creek valley to a point about five miles above the mouth of Trout creek, where it crosses that creek and swings southwesterly, passing along the southern slope of Headquarter peak and diagonally cutting across the high rugged ridge forming the divide between Bitter

creek and Lewis creek. It crosses Lewis creek at an elevation of about 3,000 feet and then swings to the south around the divide between Lewis and Barclay creeks and gradually decreases from an elevation of 2,900 feet to about 2,400 feet. Then it extends up along the northern side of Barclay creek, crosses that creek and again swings northwesterly along the north side of Index mountain ridge and, at an elevation of about 2,800 feet, again swings south around that ridge and crosses the Great Northern Railroad about one mile above Baring. The eastern boundary of this belt extends south from the north fork of the Skykomish along the valley of Howard creek to Conglomerate mountain and from there swings easterly outside the limits of the map. Between the headwaters of Howard creek and the headwaters of Trout creek, it is separated by a mass of granodiorite. The contact between the two extends along the direction of Trout creek to its head and thence down the valley of Eagle creek, which drains into Beckler river outside the limits of the map.

In the western part of the Index district an outcrop of this same metamorphic rock enters the region from the west in the vicinity of May creek and crosses the Skykomish below Reiter. From there it extends southerly across Anderson creek and along the base of West Index mountain, passing across the south boundary of the map in section 32, Tp. 27 N., R. 10 E.

GENERAL DESCRIPTION.—On account of the extreme complexity of this formation, no attempt will be made to subdivide it. The formation as a whole consists of quartzites in various stages of metamorphism intercalated with schists, slates, crystalline limestones, and cherts, together with metamorphosed interbedded lava flows.

The quartzites are in places massive and nearly white in color, occasionally having a sugary appearance. Other phases are massive and dense and have a dark color. Occasionally narrow bands are composed of fine grained pebbles which have been drawn out in lenticular fashion, while still others are conglomerates composed of chert and igneous pebbles but extensively

metamorphosed and fractured subsequent to metamorphism. These quartzite layers range in thickness from 500 feet to narrow bands less than one inch in thickness. Occasionally belts extending across country are composed of alternating layers of quartzite and schist having a thickness ranging from one-half inch to three inches which have been twisted and contorted and faulted and appear as though tied into knots so that in one square foot of area individual layers will be doubled upon themselves four or five times. This appearance is most pronounced near the contact with the granodiorite where metamorphism has been most active. On Barclay creek high steep bluffs are exposed where this type of twisting may be well observed. Other phases of this quartzite are extensively fractured and filled with small gash veins of quartz seldom over an inch in thickness and intersecting in all directions and sometimes composing more than one-half of the bulk of the rock. In the western part of the district, near May creek, this formation is exposed. It consists largely of dark gray fine grained quartzite with a smaller amount of twisted banded rock.

THICKNESS.—Because of the great disturbances which these rocks have undergone it is difficult to estimate their original thickness. An examination made of this formation in the region between Trout and Barclay creeks, and on the ridge extending westerly from Mount Index, indicates a minimum thickness of at least 10,000 feet. Three-fourths of this total, apparently, is represented by quartzite and the remaining fourth is composed of slates, schists, metamorphosed interbedded volcanic flows, crystalline limestone, and conglomeratic quartzite.

CORRELATION AND AGE.—No direct evidence has been found within this district to determine the exact age of this formation. No fossils have been found in place and any which may have existed have been completely destroyed by metamorphism. On the trail leading up May creek near the power house of the Copper Bell mine, pieces of float slate and quartzite may be found. Several of these contain fossil crinoid stems. Whether these were derived from a part of the metamorphic series could not be

determined. The underlying country rock in this vicinity is composed of a dense, extremely metamorphosed phase of quartzite, but the float specimens had not been very badly altered. The presence of the fossil crinoid stems, if derived from this formation, indicate the Carboniferous age. Studies made to the north in the valley of the south fork of the Stillaguamish river reveal the presence of similar rocks which seem to extend areally from Mount Pilchuck southeasterly to the Index district. Limestone lenses occurring in that quartzite series on the north bank of Mount Pilchuck contain large numbers of fossil Foraminifera of the genera *Fusulina* and *Orbitulina*. The presence of these organisms suggests the Carboniferous age. The general similarity of this entire metamorphic series in composition and general appearance resembles very closely that of the Cache creek formation in British Columbia,* which is known to be of Carboniferous age upon fossil evidence. Although no direct evidence can be given which will definitely correlate this formation with the Carboniferous, yet on the basis of the indirect evidence just mentioned, it will be provisionally assigned to that period.

GRANODIORITE.

AREAL DISTRIBUTION.—As may be readily seen by referring to the accompanying geological map, outcrops of granodiorite constitute by far the larger part of the areal geology within this district. This same formation is widely distributed throughout the Cascade mountains, where it forms a prominent part of the surface outcrops in the vicinity of Mount Stuart, and from there northward to the British Columbia boundary. In many places it is covered over by older metamorphic rocks, into which it has been intruded, and by later volcanic and sedimentary rocks which were laid down upon it. Wherever these have been removed by erosion the granodiorite forms the surface rock. Within the Index district this formation occupies an area of approximately 60 square miles. It makes up the larger part of the western portion of the Gunn peak mountain

*Annual Report Geological Survey, Canada, New Series, Vol. 7, 1894, pp. 37B-49B.

mass. On the south side of the south fork of the Skykomish river, it forms a belt about one mile in width and eight miles in length, lying parallel to the valley and is overlaid by the older metamorphic and later volcanic rocks. On the north side of the Skykomish river it comprises nearly all of the area within the limits of the district with the exception of a narrow belt near the mouth of Hogarty and May creeks and a small area near the mouth of Silver creek. Several smaller areas of it outcrop in the eastern portion of the district between the north fork of Trout creek and Merchant's peak, and also on the eastern side of Howard creek. Considering the Index district as a whole, the granodiorite occupies the central portion and is flanked on the east, south and west by metamorphic, volcanic and sedimentary rocks.

PETROGRAPHY.—This formation varies much in general appearance in different parts of the district and is locally referred to by the miners as granite. The most typical phase of this rock is well exposed in the Soderberg quarry, about one mile west of Index. The entire mass is here seen to be uniform in character in contrast to the mottled appearance which it possesses in many other parts of the district. Specimens collected from different parts of the quarry show a uniformity in texture, mineral composition and color. Megascopically the rock is holocrystalline, medium grained, dense, of a light gray color and breaks in large blocks with a slight tendency to a conchoidal fracture. When carefully examined the hand specimens are seen to be composed of light colored feldspars, hornblende, and varying amounts of biotite and quartz. Occasionally small crystals of apatite may be seen. A more detailed study of the feldspar crystals proves them to be plagioclase with only a very small amount of orthoclase. When examined microscopically these specimens are found to be composed of about 40% plagioclase, 10% orthoclase, 30% hornblende and biotite, and 20% of quartz, together with occasional crystals of apatite and titanite. The quartz crystals are distinctly allotriomorphic and show the usual low interference colors and the presence of

many gaseous inclusions. The plagioclase crystals, when fresh, are generally allotriomorphic but occasionally hypidiomorphic, and generally show well-defined albite twinning lamellae. A large number of crystals were chosen, which were cut as nearly as possible normal to the clino-pinacoid, and measurements were made upon them. The symmetrical extinction angles which were obtained yielded values ranging from 19° to 23° . These values indicate a soda-lime feldspar having a chemical composition of approximately Ab_6An_4 . Studies made on interference figures show the mineral to be positive, which, together with its chemical composition, identifies it as andesine. In many specimens these crystals are extremely altered and seem to be composed of clouded patches in which faint traces of albite or Carlsbad twinning may be seen. These alteration products consist largely of kaolin, calcium carbonate and quartz. The orthoclase is generally found in very small amounts and occurs in medium size allotriomorphic crystals commonly showing Carlsbad twinning and nearly always, even in the fresher specimens, some alteration. Hornblende occurs fairly abundant and can be easily recognized by its dark brown color, intense pleochroism and well defined prismatic cleavage, which upon basal sections is always found to intersect at angles of 124° . Most of the crystals have a tendency towards idiomorphism, but the crystal outlines are seldom sharp and distinct. Extinction angles measured on the clino-pinacoidal section between the C-axis and the axis of elasticity gave values ranging from 18° to 20° . These crystals are commonly altered to a dark, opaque material composed of chlorite, biotite, and a little magnetite. Biotite occurs in small amounts and can be recognized by its basal interference figure and nearly hexagonal outline. It is dark brown in color and generally more or less altered. Megascopically it can always be distinguished from the other minerals by its pronounced basal cleavage.

Among the accessory minerals are found small amounts of augite of the pale brown variety occurring in small but fairly well developed crystals and showing no pleochroism. Occa-

p. 2

4

1

1

1

1

1

1

1

1

1

1

sional slender prisms of apatite and zircon were noted. These minerals are nearly idiomorphic and the latter can be at once recognized by its very high index of refraction.

The above description indicates a rock of intermediate chemical composition and the presence of the andesine variety of plagioclase together with the very small amount of orthoclase places it in the diorite family. The presence of a considerable amount of quartz indicates an acid phase of the diorite or what is generally known as quartz-diorite or granodiorite.

In other parts of the district this granodiorite varies very much in character. About five miles northeast of Index in the vicinity of the Ethel Consolidated mine, it is characterized by the presence of many basic secretions in the form of ovoid or spherical patches scattered through the rock. When examined under the microscope these are seen to be composed largely of hornblende and biotite to the exclusion of the lighter colored minerals. These dark patches range in size from one square inch to ten square feet or more. Their origin is believed to be due to the segregation of the more basic elements at a number of centers in the molten magma just prior to solidification, resulting in the crystallization of the more basic minerals about those centers. The lighter colored portions of the granodiorite also vary in texture and in the varying proportions of the constituent minerals. Sometimes biotite predominates as the most important essential mineral. In other places hornblende predominates and occasionally both are almost entirely absent and the rock is composed chiefly of plagioclase and quartz. At times the rock is slightly porphyritic and seems to be composed of a granular ground-mass made up of allotriomorphic crystals of plagioclase, quartz and hornblende, with larger, slightly hypidiomorphic crystals of the same mineral embedded in it. This phase is more common in the near vicinity of the overlying metamorphic rocks, as may be seen on Barclay creek and in the smaller intrusive masses on Howard and Lost creeks. In the mine workings on the Merchant group on the upper portion of Trout creek, small, isolated, irregular shaped masses

of granodiorite occur within the metamorphic rock in a zone about five hundred feet in width and extending along the granodiorite-metamorphic series contact. Specimens taken from these small intrusions represent wide variations in mineral composition. Some are very coarse grained and contain a large proportion of hornblende and biotite, while others are finer grained and are made up almost entirely of plagioclase and quartz. The same is true near the contact in the main tunnel at the Copper Bell mine in the western part of the district. On the south side of the Skykomish along the north slope of Mt. Persis, at an elevation of 1,700 feet, this rock has a reddish to bluish tinge and is found upon microscopic examination to contain a small amount of nepheline, with very little quartz, which indicates a closer relation to the syenite family than to the diorite. At first glance these rocks might appear to belong to two distinct intrusive masses, but upon a careful examination in the field this phase seems to be only a differentiation from the granodiorite proper.

CONTACT RELATIONS.—Along the contact between the granodiorite and the Gunn peak metamorphic series many interesting contact relations may be seen. On the divide between Barclay and Lewis creeks the metamorphic quartzite and schists stand out in bold, crag-like fashion and at an elevation of about 3,000 feet are found to lie in contact with the underlying granodiorite. Specimens collected on this contact in a zone about six inches wide, show the development of large crystals of biotite and muscovite, some of which are over eight inches across. These are chiefly developed in the granodiorite, but lie directly in contact with the metamorphic rocks. Biotite in smaller amounts is also developed in the fissures and vein fillings in the quartzite at some distance from the main contact. The contact line is often sharp and distinct. In the locality just mentioned the metamorphic rocks which consist largely of banded and contorted quartzites having a gneissoid appearance, stand with their stratification planes nearly vertical, and the plane of contact with the granodiorite normal to their strike. Locally

the direction and pitch of the plane of contact varies considerably, but in general the metamorphic series dip away from the granodiorite. In a zone lying in the metamorphic series and extending more than 1,000 feet from the granodiorite contact there have been developed irregular scattered crystals of garnet, epidote and hornblende. This may be well observed on Uncle Sam creek from a point at an elevation of 3,200 feet up to the summit of the ridge. In other places, as on Lost creek, the metamorphic quartzite seems to have been considerably shattered, thoroughly impregnated with the more acid phases of the granodiorite magma and then re-cemented by it.

GRANODIORITE APLITE.

Dikes of this rock are quite generally distributed throughout the Index district. It is a light colored, fine grained rock, which is sometimes hard and vitreous, resembling fine grained quartzite. More often it is composed of very small crystals, of quartz, andesine and orthoclase, with some biotite and hornblende. Some of the narrower dikes have a very little hornblende and biotite, or even none at all. These dikes have no general direction and vary in width from one inch to over one hundred feet. The walls are always sharp and well defined and the rock is chemically more acid than the granodiorite. Often in the field it might be mistaken for quartzite. The majority of the outcrops are so small that they have not been represented on the geologic map. It is generally much more resistant to weathering than the granodiorite and stands out comparatively fresh while the latter is more or less altered.

These intrusions are presumed to have been nearly contemporaneous with the Index granodiorite, and to represent more acid differentiations from the deeper part of the magma which have been drawn up into cracks formed in the roof of the partially consolidated batholith. These cracks are supposed to have been formed by contraction of the roof at the time of solidification. The vein fissures cut through these the same as they do the granodiorite.

ANDESITE PORPHYRY DIKES.

These intrusive rocks are found on Howard creek and on the divide between that creek and Trout creek. They are irregular in shape, and have a general east-west trend. In many places they cut up through the granodiorite and metamorphic series in narrow intersecting dikes so that it is impossible to represent them upon the map. One dike lies on the east side of the canyon near the workings of the Co-operative mine. About three miles above the mouth of the creek it forms a part of the west side of Spire mountain and has given rise to boulders of tremendous size, which have come down from the mountain side. It is a dark gray medium grained rock and ranges in structure from granitoid to porphyritic. Under the microscope it is seen to be made up of feldspar ranging in chemical composition from basic labradorite through bytownite. In several slides, acid anorthite was found. The dark minerals are hornblende with enstatite and augite. These crystals are generally subhedral, but often distinctly idiomorphic. In the more porphyritic varieties, the groundmass is composed of small granitoid crystals of labradorite and bytownite with grains of augite and small crystals of hornblende.

This rock is older than the Howard arkose series and may possibly belong to the early Miocene, although no definite statement can be made to that effect.

WEST INDEX ANDESITIC SERIES.

AREAL DISTRIBUTION.—Rocks grouped in this formation outcrop to the southwest of Index in the high mountain ridges forming Mount West Index, and Mount Persis. They cover about four square miles of area within the district and rest unconformably upon the Index granodiorite and the Gunn peak metamorphic series. They outcrop about one-half mile south of the Skykomish river below Reiter, at an elevation of 1,400 feet. From there the contact swings southeasterly across Anderson creek up to the base of Mount West Index at Lake Serene and then passes across the south boundary of the map in section 32.

GENERAL DESCRIPTION.—The rocks composing this formation consist of a complex mass of intercalated layers of fine grained andesitic breccias, conglomerates, and badly altered lavas. The base of the series is exposed at the base of West Mount Index at the level of Lake Serene (2,050 feet). They rest upon granodiorite and quartzite and dip away to the southwest at an angle of about twenty degrees. The total thickness of the series is between twenty-five hundred and three thousand feet. The rocks are gray, but often have a greenish tint. To the naked eye, they closely resemble andesite flows, although many specimens appear to be made up of angular fragments of andesitic material less than one inch in diameter. The texture of this variety can only be detected by careful observation, and they seem to be flow breccias. Other beds are found to contain fragments of quartzite and granite, indicating their partial sedimentary origin. The lavas are medium to fine grained, gray and phenocrystalline. Small lath shaped feldspars with larger crystals of augite lie scattered about in a darker fine grained groundmass.

When subjected to microscopical analysis, many of the specimens which appeared to be lavas, were found to contain many angular and partially waterworn fragments of quartzite, together with re-cemented tuff and andesite. Those specimens which could be classed as lavas, contained phenocrysts of labradorite and augite, embedded in a fine grained groundmass composed of microlite laths of acid labradorite and augite. Occasionally hornblende and enstatite phenocrysts could be determined.

The members of this series grade into each other, but the larger part of the formation is composed of andesite lava.

CORRELATION.—The age of this series of rocks cannot definitely be stated. No fossils occur in it. In some investigations carried on by the writer in the Puget Sound basin and in the western foothills of the Cascades, about ten miles west of the Index district, lavas similar in general appearance and composition rest beneath Oligocene marine fossiliferous beds and

above the Eocene brackish water beds. The areal distribution of these were traced eastward towards Mount Index, but not to it. It is quite possible that they are a part of the same formation and if so the age can be set down as late Eocene. It is also possible that the West Index formation may also be of the same age as the Howard arkose formation, but sufficient evidence is not available to make such correlations at the present time.

HOWARD ARKOSE FORMATION.

GENERAL DESCRIPTION.—This formation consists of from five to seven hundred feet of coarse, angular arkosic conglomerate with interbedded tuffs, lavas and andesitic breccias. The basal formation is arkosic in character and chiefly made up of small and large angular and rounded boulders of granodiorite, quartzite, chert and lava, embedded in a matrix composed of fine sand grains and volcanic ash. The boulders range in size from less than one inch up to two feet. An excellent exposure may be seen in a cut on the west side of Howard creek, just below Howard lake. Near the middle of the section small lenses less than five feet in thickness of andesitic tuff and lava are interbedded and lie nearly horizontal. Above this a large per cent. of the boulders are composed of andesite and in places the formation becomes an andesitic breccia. On the divide between Howard and Trout creeks, on the ridge leading up to Conglomerate point, the top of this section may be seen. It is composed almost entirely of andesitic breccia. Examinations of thin sections of this rock show the presence of phenocrysts of labradorite, augite and hornblende embedded in a fine very much altered groundmass composed of small microlites of labradorite and grains of augite.

AREAL DISTRIBUTION.—It is limited in distribution and within the district is known to occur in place only near the head of Howard creek on the divide between that creek and Trout creek, where it forms the knob known as Conglomerate point. It is underlain by granodiorite and quartzite and on the Howard creek side the contact extends up the valley slope diagonally to

the divide with Trout creek in a northwesterly direction. It swings around the west side of Conglomerate point and reaches Howard creek again at the lake. It has been folded down into the quartzite and possibly the north side may have been let down into the granodiorite by a small fault.

On May creek, above the Copper Bell mine power house, large angular boulders of float material were found, similar to the Howard creek rock, but a careful search on the mountain sides up to the head of that creek failed to reveal any such deposits in place. There may have been, however, small outlying patches of it which escaped detection in some of the more inaccessible localities, or it may have been brought there by glaciers.

On the ridge forming Mount West Index and Mount Persis, andesitic breccias, arkoses and lava flows occur, which may possibly be the same as those on Conglomerate point. They are undoubtedly similar in origin, but they are quite different in appearance.

CORRELATION.—There is no means of determining the geologic age of this formation in this district, except that it is Tertiary. No fossils of any description could be found. It overlies unconformably the Index granodiorite, the Gunn peak metamorphic series and the basic intrusive dikes on Howard creek.

To the north in the Monte Cristo district, Spurr* has described an arkose formation of Eocene age composed of pebbles of granodiorite with some quartzite and old andesite lava flows. In that district it is the oldest of the Tertiary group. That on Howard creek is undoubtedly much younger, and may belong to the Miocene. It is in places thoroughly stained with copper and occasionally contains disseminations of chalcopyrite and pyrite.

OLIVINE DIABASE.

This rock has been observed at one locality only. It outcrops as a vertical dike about twelve feet wide with a trend of S. 36° E. and cuts across the Great Northern Railway track

*22 Annual Report U. S. Geological Survey, p. 788. 1900.

just below Sunset Falls. It cuts up through the granodiorite.

This rock is black and badly altered. To the unaided eye it is fine grained, dense and breaks with a conchoidal fracture. It is seen to contain very small crystals of pyrite scattered through it. Under the microscope it is found to contain phenocrysts of olivine and bytownite embedded in a groundmass composed of small bytownite laths and augite. The groundmass has the typical ophitic structure and the phenocrysts are generally small.

QUATERNARY.

Deposits of Quaternary age are abundant in the district and consist of extensive accumulations of glacial drift, stream alluvium and talus material.

GLACIAL DRIFT.—The glacial drift comprises sand, clay, sandy clays, silts and thick deposits of assorted and non-assorted gravels. To the west of Index in the Skykomish valley, these deposits attain a thickness of 500 feet. To the east they gradually become thinner, but form a veneer over the bedrock formations and over the valley slopes. Along the north fork of the Skykomish river the drift is made up of fine gravel and erratic boulders, strewn over the hillsides to an elevation of more than 500 feet above the level of the river. The same is true on the south fork. Near the junction of these two forks, just south of the town of Index, thick deposits of blue clay overlie the bedrock and this in turn is overlaid by partially stratified gravels and sands. About two miles west of Index along the Great Northern Railway cut, beautiful sections may be seen composed of alternating bands of gravelly sands, clays and washed gravel. Cross bedding is very noticeable as well as minor faults. These bluffs have been formed by the downward cutting of the river.

The present condition of the glacial deposits is to be explained by considering the pre-glacial river channel to have been filled with the same material as now occurs in the steep cliffs, by the action of streams issuing forth from beneath the glacier as it retreated to the east, together with material dropped from the surface of the glacier at its margin as the ice front melted. Later, due to an uplift of the entire Puget

Sound region, the Skykomish river entrenched its channel through this accumulated drift until it reached its present level, leaving as remnants the present glacial bluffs on either side of the river as well as deposits beneath it, which have not as yet been cut into. The materials comprising this glacial drift have been derived in part from the rocks occurring within the district and in part from those around the various streams draining into this river.

ALLUVIAL DEPOSITS.—These deposits are limited to the floors of the larger stream valleys and consist of materials deposited by the streams since the retreat of the glaciers. The materials are gravels, sands and clay, which in some places, as near the town of Index, attain a thickness of 20 or more feet. The main valley of the Skykomish has meandered from side to side through its canyon and deposited a considerable volume of material. In many places quicksand has been reported at depths of fifteen feet. A small amount of placer gold occurs irregularly distributed through this material and was the occasion for the earliest settlements in the Index district.

TALUS DEPOSITS.—These deposits are characteristic of all the valleys within this district. All the high mountain ridges contain talus slopes extending more than half way to the summit of the ridges. This material is formed by the weathering of the mountain masses and the numerous snow slides occurring during the winter season. Thousands of tons of rock are brought down each year onto their slopes. One of the best examples of this may be seen in the valley of Howard creek, where great deposits lie along the slope of Spire mountain and along the eastern slope of Iron mountain. Surrounding all of the high glacial lakes are talus deposits composed of angular blocks derived from the precipitous walls surrounding these former glacial cirques.

STRUCTURE.

Among the more important structural features of the region is a great central mass of granodiorite surrounded by older

metamorphic sandstones, shales, limestones and lava flows into which it had been intruded during Jurassic time. The contact plane between the granodiorite and metamorphic series is not horizontal, but varies. In most localities where it could be studied it is nearly vertical and in one place the igneous mass had been partially turned over on to the metamorphics. This was caused by a small local fault. On the upper part of Trout creek on the south side of Headquarters peak near the Merchant mine, this vertical contact is well represented. It is not a fault plane, but distinctly an intrusive contact with occasional apophyses of the granodiorite extending into the quartzites. A few local faults have occurred here, but they are unimportant.

Farther to the west on Barclay creek the contact may again be seen. The quartzites pitch very steeply away from the granodiorite, but farther to the south on the south side of that creek the plane of contact becomes more nearly horizontal.

On the divide between Trout and Eagle creeks, the eastern contact of these same formations may be seen. The intrusive granodiorite underlies the quartzites and the plane of contact dips to the west at an angle of 45° .

This belt of metamorphic rock seems to occupy a trough in the granodiorite with a general north to south direction. This can be accounted for only by an axial downfold. The time of folding cannot be determined, except that it had occurred in part at least prior to the deposition of the Howard conglomerates.

In the southwestern part of the district the West Index andesites rest unconformably upon the Index granodiorites and the metamorphics. They have suffered very little folding and dip at an angle of about twenty degrees to the southwest.

Later structural movements, probably closely associated with the final uplift of the Cascade mountain mass, produced numerous joint planes, the more prominent of which were avenues for ascending mineral bearing solutions to deposit the ores. The joints and fissures fall into several classes with certain directions of strike. The stronger and more pronounced joints have a

predominant strike of N. 75° W. in the eastern part of the region and those in the west average N. 45° E.

The minor ones make various angles to these, but they more commonly intersect them at angles of twenty or thirty degrees. The major joints pitch at a very steep angle to the south; the minor ones have no predominant pitch.

GEOLOGICAL HISTORY.

The geological history of the Index Mining District is represented by sedimentation, volcanic extrusions, batholithic intrusions, folding, faulting, uplift, erosion and glaciation. Concerning the paleozoic history of this region, we have no knowledge at all, unless a part of the Gunn peak formation may have been deposited during that time. Throughout the Cascade mountains no rocks have been found which from palaeontological evidence could be definitely assigned to the Paleozoic. On some very scanty and indirect evidence certain rocks within this district are provisionally assigned to the Carboniferous. They are now extremely metamorphosed, but originally represented sandstones, shales, interbedded sandstones and shales, limestones and volcanic flows. These appear to have been laid down in marine waters and to represent sediments deposited in Carboniferous and perhaps Triassic and Jurassic seas, which are known to have been extensive on the west coast of North America during that time. Concerning any movements which may have affected these sediments prior to the intrusion of the great batholith of granodiorite, we have no knowledge. The time of intrusion of this batholith is pre-Tertiary and the evidence is based largely upon fossils collected in the Eocene arkoses described by Spurr in the Monte Cristo region. A part of this same granodiorite mass can be traced to the southward in the Mount Stuart and Snoqualmie quadrangles where it underlies unconformably Eocene sandstones.

The effects of this granodiorite intrusion were to metamorphose the older sediments, producing quartzites, slates and crystalline limestones.

The geological record of the larger part of this district has

been completely destroyed by erosion and the deciphering of the history of the region is purely hypothetical.

During early Tertiary times the region to the north of Index as well as to the south, was covered with a series of fresh water or brackish water lakes or estuaries, in which conglomerates and sandstones were accumulating. In the Monte Cristo district these have been described as the early Arkose formation and upon fossil evidence have been placed in the Eocene. In this district a small outcrop of similar material occurs near the head of Howard creek and upon a stratigraphical basis is considered as being a remnant of one of these lakes. The remainder of Tertiary time in the Index region is represented by outpourings of volcanic lava and intrusions of basic dikes. These dikes are found in the Howard creek region in the eastern part of the district and may have been the source of volcanic flows similar to those in the Monte Cristo district which once covered this region, but have since been removed by erosion. In the southeastern part of the district a thick series of volcanic flows of andesite dip off to the west. Their age cannot definitely be determined, but they correspond very closely to a series of andesites which appear to be coextensive and occur farther to the west south of Monroe and underlie the marine Oligocene of the Puget Sound basin.

During Tertiary time this part of the Cascades, in common with the eastern portion, appears to have undergone many physiographic movements which finally resulted at the close of the Pliocene, in the uplift of the entire range as a great deformed dome. This uplift is assumed to have produced a series of structural northwest-southeast warps which determined the present position of the Skykomish and Skagit valleys, as well as the Wenatchee and Yakima on the eastern side of the mountains.

Early in the Pleistocene the precipitation became excessive and the climate colder, resulting in the accumulation of great snow fields with resultant glaciers, which ultimately flowed down the stream valleys to Puget Sound, where they united and together with ice streams from the north, formed a great pied-

mont glacier. Later these glaciers melted and retreated up the stream valleys, leaving strewn over their former course, sands, clays, and glacial boulders. Their work in the mountains was to accentuate the topography, giving it its characteristic sharp, ragged appearance.

CHAPTER III. ECONOMIC GEOLOGY.

HISTORY OF MINING.

Prospecting and mining in the western portion of the Cascades in Snohomish and King counties did not become active until 1885. In 1874 the first mining claims are said to have been located on Silver creek, but no further development work was done until 1882, when prospecting began on the north fork of the Skykomish near the mouths of Silver and Troublesome creeks. A trail was cut through from Gold Bar up the valley past the present townsite of Index to Silver creek. In 1890 the towns of Galena and Mineral City were laid out and the first settlement at Index made near the junction of the north and south forks of the Skykomish by Mr. Gunn. This consisted of a small one-story lodging house and store—the nucleus of the present town. About this time rich placers were found and located in the valley of the Sultan basin, and as a result of the excitement there, many claims were staked out along the Skykomish river valley from Gold Bar on the west, eastward to Silver creek. In 1892 the western division of the main transcontinental line of the Great Northern Railway was being constructed from Everett eastward up the valley of the Skykomish to the summit of the Cascades, and about two years later a wagon road was cut through from Index to Galena, partly by the county and partly by the miners. A small station was built on the railway just west of the present site of Index and the town became the natural base of supplies for the surrounding mining camps. Under these conditions, prospecting became active over the entire region and a large number of claims were located. The earliest locations made within this district were on Howard, Lost and Trout creeks. In 1892 Andrew Merchant discovered and located several ledges on the upper portion of

Trout creek and John Wallace several on Lost creek. Later, in 1899, Charles R. Howard located a group of eight claims on a series of east-west veins situated about one mile below Howard lake on Howard creek, and a group of four claims about one mile to the north of the same creek.

During the period from 1897 to 1902 mining activity reached the highest point of development and the majority of the claims of the district were located. On June 19th, 1907, Ezra M. Egbert and Arthur C. Egbert located the Sunset lode claim on Trout creek; John Lewis the Non Pareil on the same creek in the same year; C. H. Gray and L. W. Gray the Copper Bell on May creek, and A. M. Watt and Charles E. Cummings the Gunn Peak claims. Shortly after their location many of these claims were incorporated. In July, 1897, the Sunset claims were incorporated as the Sunset Mining Company and the Copper Bell claims in May, 1897, as the Copper Bell Mining Company. In 1900 the latter was reorganized as the Bunker Hill-Sullivan Copper Mining Company and finally in 1902 as the Bunker Hill Mining and Smelting Company. The Ethel claims on Ethel creek, about five miles east of Index were located in 1900, and incorporated in 1905 as the Ethel Copper Mining Company. In March, 1903, the Non Pareil claims were incorporated as the Non Pareil Copper Mining Company.

During this period of time extensive development work was undertaken and several large ore bodies were uncovered and mined. A surface tram was built from Index up the south side of the north fork of the Skykomish to Trout creek, a distance of nearly five miles, and from there a gravity surface tram for a distance of 1,300 feet extending up the mountain side. Finally the surface tram was continued for one mile to the Sunset mine. Several carloads of ore were taken out and shipped to Index, unloaded at the end of the tram and transferred to the Great Northern Railway freight station and from there shipped to the Tacoma smelter. Much of this was not sorted, which resulted in the shipment of some very low grade ores. The other properties in the district with the exception of the Copper Bell

were not connected with the railroad by tram and were compelled to bring any ore to Index which they might wish to ship, by wagon or on horseback. The heavy cost involved in hauling the ore, in bringing it to the railroad and the fact that the average ore was uniformly low grade, made mining at a profit prohibitive. About this time the price of copper dropped to twelve cents per pound and mining activity in this part of the Cascades rapidly declined. During the last six years, development work has been confined almost entirely to the required assessment work. Several properties have been patented and their development has entirely ceased. In general it may be stated that the lack of suitable transportation facilities from the mines to the railroad and the low grade character of the ores are responsible for the present inactivity of mining in this district.

At present the Index Galena Lumber Company is building a wide gauge track from the Great Northern Railway at Index up the south side of the north fork of the Skykomish for the purpose of bringing out timber and it is their intention to extend the line up the river indefinitely. One mile has already been built. With suitable transportation many of the properties, notwithstanding the low grade of ores, could be mined at a profit.

TREATMENT OF THE ORES.

The ores in this district are primarily copper and the silver and gold values which occur in small, but varying amounts are not considered in the treatment of the ores. The total amount of ore which has been shipped to Tacoma and Everett is not large. The general practice has been to sort out the rich ore, sack it and transfer to Index by pack train or wagon and ship from there to the smelters.

Two of the properties have erected concentrating mills and ship the concentrates. The Bunker Hill Mining and Smelting Company constructed a mill which was put into operation in April, 1905. It has a capacity of fifty tons of ore per day and contains a No. 2 Austin gyratory crusher, three sets of rolls, coarse, medium and fine, one Johnson vanner, one Dodd buddle, and three Wilfley concentrating tables, one Calumet and

one Montana classifier, one dryer for the concentrates and one Cleveland-Knowles magnetic separator, used for the purpose of extracting the iron from the concentrates. There is a 35-horse-power engine which can be driven either by steam or compressed air. The plant has a present capacity of 50 tons per day, but it is so arranged that by adding tables or rolls it can be increased to 75 or 100 tons.

PRODUCTION.

No reliable estimate can be obtained as to the amount or value of the ore produced in this district. The ores are mainly copper and those which have been shipped out, have been sent to the Tacoma smelter. The mines which have produced and shipped ore are the Ethel, Sunset, Wilbur Index and Copper Bell. Some of the other properties may have shipped small amounts, but no information could be obtained. Ten carloads are said to have been shipped from the Sunset, which is said to have averaged 5% copper. The Ethel mine and the Copper Bell have concentrating plants, but the amount of ore shipped is not known. Two carloads are said to have been packed out from the Wilbur Index mine on horseback and shipped to the smelter.

Many of the properties have ore on their dumps and several have it sacked ready for shipment provided suitable transportation could be obtained. The ores are low grade but several of the mines could be worked at a profit if transportation were available and the extra cost of handling were eliminated.

DISTRIBUTION OF THE ORE BODIES.

Mineral veins are very evenly distributed over the entire district and are found in the granodiorite, quartzite, aplite and andesite porphyry. Since the largest part of the areal geology of the district is granodiorite, the larger number of veins are found in that rock. Observations seems to show, however, that the veins occurring in the metamorphic rocks contain a larger amount of pyrite and a smaller amount of copper ore, than in the granodiorite. Assays made on a large number of samples

yield much higher values in silver and gold in the former than in the latter, although none of them run over \$4.00 per ton. The richest and largest ore bodies which have been encountered in mining development seem to lie in a curved belt extending in a general east to west direction in the middle of the district. Ore bearing veins occur to the south and north of this belt, but they are neither so wide nor persistent in length as in the zone just mentioned. Those in the south are better developed than those in the northern portion.

CHARACTER OF THE ORE BODIES.

STRIKE.—All the fissure veins in this district do not have uniform direction of strike. One of the most common features, however, is their arrangements in a semi-circle with the convex side facing northward. There are a few of the veins which do not conform to this, but as a rule they are small and of not very great importance. In addition to the fissures which have been mineralized there are many fracture or joint planes, and observations made on the strikes of these show the stronger ones to have nearly the same direction as the more prominent fissure veins. Both the fissure veins and joint planes may be grouped under major and minor directions. The veins conforming to the major directions in the eastern portion of the district have a general strike of north 75° west, as may be seen in the Sunset, Non Pareil, and Howard Creek properties. Farther to the west in the Ethel mine the general strike becomes more nearly east and west and in the western part of the region on May creek it averages N. 45° E. The divergence to the south in the western portion of the district on one side of the arc is much greater than on the other side in the eastern part. In the south and central part in the vicinity of Gunn peak, the two directions of strike bend more sharply and finally become parallel to each other, where each extends north and south. The directions of the minor veins and joints vary considerable, but as far as could be determined the larger number intersect the major ones in the different parts of the district at an average angle of 30° .

PITCH.—The veins in the region of Howard and Trout creeks pitch to the southwest, and on May creek in the vicinity of the Copper Bell mine they are nearly vertical, but occasionally dip to the south at angles varying from 80° to 90° . The minor joint planes have a wide range of dip, but from over one hundred observations taken in different parts of the field, 60% were found to average about 40° to the northeast, north and northwest.

SHAPE.—Many of the veins in this district can be traced for a long distance on the surface, but when tapped at depth are found to become narrower, wider, or to pinch out altogether. Often they seem to vary much in width on the surface. Several ore bodies of this character have been opened up and the ore extracted, and upon examination these are found to be lens shaped. These lenses seem to become narrower above and below and forwards and backwards. They lie in the plane of the fissure vein and are portions of the vein which are much wider than the average and are filled with ore. In many places the wall rocks lie in contact with each other, with merely a thin seam of quartz or clay between them. In such cases the veins are generally considered to have pinched out, but that does not necessarily mean that they will not widen again and become large lens-shaped ore bodies.

INFLUENCE OF THE COUNTRY ROCK ON THE ORES.

The veins in this district lie in granodiorite and quartzite, and the larger number occur in the former. The quartzites contain many veins filled with copper minerals, but as a rule the per cent. of copper is much lower than in the veins in the granodiorite. Pyrite is more abundant as well as gold and silver, although the latter two do not occur in paying quantities. Whether the country rock is responsible for this condition, or whether the solutions which supplied the mineral matter were, cannot definitely be stated. Within the granodiorite belt proper, the country rock seems to have had very little effect on the ores. In many cases ore bodies seem to lie in close

proximity to narrow granodiorite porphyry or aplite dikes, but no definite relation between those dikes and the veins could be determined. The width of the fissure zones has partly determined the size of the ore bodies. Observation made on veins in the quartzite and granodiorite indicate that the fissures in the latter are more regular, while those in the former are smaller and intersect one another, which allow the solutions to travel in many diverging channels. This has resulted in the formation of a network of small intersecting seams and in the impregnation of the country rock in the quartzite areas. Many of these low grade veins might be worked if the values were not scattered through so large an area of country rock. The hard and resistant character of this rock renders the profitable mining of many of these low grade ores in the quartzite impossible. The granodiorite is fully as hard to tunnel in, but the ores are generally more concentrated in it.

ALTERATION OF THE COUNTRY ROCK.

Because of the excessive rainfall, rapid erosion and unusually thick covering of vegetation, alteration of the country rock has not extended so far as in many of the dryer and arid mining districts. As a rule the rock is nearly fresh and unaltered at the grass roots. In the fissure zones, however, the conditions have been such that alteration has extended for considerable depths, due to downward percolating surface waters. Below the zone where these waters have been active, heated waters from another source have affected the wall rocks. These solutions were those which originally carried the mineral matter from some deep underlying magma to the fissure zone, and in ascending in them precipitated part of the mineral salts, and chemically acted upon the more soluble mineral in the wall rock, and also in the crushed and softened fragmental rock in the fissures. Wherever open fissures existed, they were filled with mineral, but where they were choked up, the solutions in permeating through them dissolved the more soluble portions and replaced them with ore or silica. These solutions have travelled through the wall rocks as well as through the fissures

proper, with the result that the former are often very much altered and impregnated with sulphides and silica.

To a certain extent this has been partly responsible for the size of some of the ore bodies. The ore body in the upper workings of the Ethel mine has apparently been formed in this way. It is probable that the portion of the fissure vein representing this ore body was originally wider than the average portion of the fissure, allowing the solutions more freedom to circulate, but in places the character of the gangue indicates that this broad portion of the fissure must have been nearly filled with crushed granodiorite. As the solutions travelled upward through this zone they seem to have extended out into the wall rock also, and the vein resulting from this method of ore deposition must be partly considered as a fissure and partly as a replacement vein.

The process of alteration in the granodiorite involves the breaking down of the feldspar, the extraction of potassium, sodium or calcium, and the formation of kaolin. In many cases the wall rocks do not show any appreciable alteration, even in the near vicinity of the vein. In other cases they are thoroughly decomposed and more or less altered for a distance of one hundred feet or more from the vein. As a rule, in the distinct fissure veins which are narrow and filled with banded ore, the wall rocks are not badly altered, but when the ore bodies are large the solutions have been much more active and as a result the country rock is altered for a long distance away from the walls. Sometimes the alteration of the wall rock is so great that it is impossible to distinguish between that and the vein proper. When alteration is noticeable in the walls, small isolated crystals of pyrite, chalcopyrite or bornite are found scattered through it, but seldom in sufficient amounts to consider the wall rock as ore. In many cases silica has been precipitated from these solutions so as to practically re-cement the altered wall rocks. The alteration effects just mentioned are assumed to have been caused chiefly by upward ascending solutions at the time of the original deposition of the ores.

Descending surface solutions have also played some part in the alteration of the wall rocks. One of the most frequent effects of these solutions is the deposition of the calcite and the secondary enrichment of the chalcopyrite to bornite, chalcocite, cuprite and other oxidized copper ores.

MINERALOGY.

The minerals comprising the ores of this district are chiefly chalcopyrite, pyrite and bornite, carrying small amounts of silver and gold. The latter are, however, more intimately associated with the pyrite than with the copper minerals. In addition to the sulphides just mentioned the lead sulphide, galena and the zinc sulphide, sphalerite are occasionally found, but they are unimportant. The gangue minerals are mainly quartz, together with calcite, sericite and very rarely fluorite. The enriched products in the upper portions of the veins are chalcocite and bornite, together with the oxidized minerals; cuprite, malachite and micaceous hematite.

PYRITE.—This sulphide is widely distributed throughout all of the veins in the district. It occurs both in crystalline and massive form. In some places it is disseminated in small grains through both veins and wall rock. In others it occurs as small bands, stringers, or irregular shaped masses. It is light yellow and very often intricately mixed with chalcopyrite with which it seems to be synchronous in origin. As a part of the vein filling, it is more common in the metamorphic rocks than in the granodiorite. It has been altered near the surface to micaceous hematite and limonite.

CHALCOPYRITE.—This is the most common mineral of copper in the district. It is generally found massive and seldom as crystals. Often large masses of it occur several feet in diameter with no impurities, but it is generally associated with pyrite and quartz or disseminated in the wall rocks as small kernels, for some distance away from the vein. It is more common in the deeper portions of the vein than near the surface, where it is often partly enriched, forming bornite.

BORNITE.—In several of the mines bornite is the predominant copper ore. It is always more prominent in the upper part of the vein and gradually decreases in depth. When broken it is often found to form a shell around the inner kernel of chalcopyrite, showing the effects of enrichment by downward leaching. In some veins it occurs in pure massive form in bands varying in width from two inches to one foot, and in others in small grains about the size of a pea scattered about in the matrix of crushed granodiorite largely altered to sericite and quartz and cemented by secondary silica derived from solution. This condition prevails in the ore body at the Ethel mine.

CHALCOCITE.—This mineral does not occur in large quantities nor in all parts of the district. It is more closely associated with bornite than with the chalcopyrite and forms small irregular seams extending through the former. It also occurs in irregular bunches in the sericite gangue of the veins.

CUPRITE.—It is found in the upper portion of some of the veins, especially in the surface outcroppings. It is an oxidation product from the original chalcopyrite.

MALACHITE.—It is widely distributed near the surface, but only as a coating on the other minerals or rocks. It is an oxidation product.

GALENA.—This mineral occurs occasionally in all of the veins, but seems to be more prominent in and closely associated with the pyrite veins in the metamorphic series than with the chalcopyrite. It occurs in the form of small isolated crystals and is quite conspicuous in the quartz veins on Lost creek.

SPHALERITE.—It is less common than galena but occurs in a similar manner. It is found in small amounts in the veins on the north side of Ethel creek.

HEMATITE.—It is very common in nearly all of the veins in the district, and occurs near the surface, generally as a capping to the copper veins. It has resulted from the decomposition of the chalcopyrite and pyrite and the oxidation of the iron.

The copper has been taken into solution and carried downwards where it has enriched the unaltered chalcopyrite and resulted in the formation of bornite. Most of the hematite is of the micaceous variety and contains scattered through it small kernels and unaltered irregular shaped masses of chalcopyrite and bornite.

LIMONITE.—It is found near the surface as a rusty mass, coating the quartz or vein material. It has also resulted as in the case of the hematite from the decomposition of the chalcopyrite and pyrite.

QUARTZ.—Quartz is the most common gangue mineral and has resulted partly from the alteration of the crushed granodiorite in the vein, and partly from the mineral solutions from below which brought up the copper and iron sulphides. It is generally massive and is a cementing material for the metallic minerals, but sometimes occurs in well formed, prismatic, pyramidal crystals.

CALCITE.—Calcite is fairly common as a gangue mineral, but seems to be best developed in those veins near the quartzite-granodiorite contact. It is a conspicuous mineral in the veins in the Ethel mine and has formed subsequent to the primary deposition of the ores.

STRONTIANITE.—It occurs in a narrow seam about four inches wide in a vein on the north side of Ethel creek.

HORNBLLENDE.—This is a common vein mineral in the near vicinity of the granodiorite-metamorphic series contact. It is abundant on the north side of Barclay creek in the quartzites at the Uncle Sam mine where it occurs in crystals ranging from two millimetres up to five inches in length. With it are associated epidote, calcite, pyrite, chalcopyrite, garnet and hematite. It is also found with the copper ores at the Copper Bell mine, but there it is not far from the quartzite contact.

GARNET.—It occurs in crystals up to an inch in diameter along with hornblende and epidote on the north side of Barclay creek in the quartzite.

SERICITE.—It is common in the veins where it has resulted from the decomposition of the silicates in the granodiorite.

KAOLINITE.—Occurs in considerable quantities in the veins, especially near the walls, and has resulted from the decomposition of the aluminous silicates forming the veins and walls.

FLUORITE.—It was noted at one place only. In the upper portion of the Ethel vein several crystals were found with bornite and calcite in a matrix of decomposed granodiorite partially re-cemented with silica.

SILVER.—No mineral of silver was seen. Assays made on quartz containing pyrite taken from Lost creek and Howard creek gave returns of two and five-tenths ounces to the ton. Assays made also upon micaceous hematite samples collected in the Florence-Rae tunnel on the west side of Trout creek gave low values in silver. A larger number of assays gave only a trace.

GOLD.—Gold occurs similar to silver and the highest assays obtained were 0.2 ounces to the ton.

GENESIS OF THE ORES.

The ore deposits of this district occur in distinct fissure veins and in veins which are partly fissure and partly replacement. In the eastern part of the district the veins have a general strike of N. 75° W. and in the western a strike ranging from N. 45° E. to N. 10° E. and a nearly constant pitch at a very steep angle to the south. These fissures extend through the granodiorite and Gunn peak metamorphic series as well as a number of later intrusive dike rocks. The ores are chiefly sulphides of copper and iron together with small amounts of gold, lead, and zinc. The gangue material is largely quartz.

These ores are assumed to have been derived from the deeper portions of the earth's crust by the action of ascending solutions under high pressure and temperature. The definite character of these deep seated rocks which supplied the mineral matter and the date of mineralization cannot absolutely be determined.

There seems to be evidence for considering the Gunn peak metamorphic formation as a series of sandstones, shales, limestones, and lava flows which were laid down on the sea floor during the Carboniferous or possibly Triassic or Jurassic times. There seems also to be justification in considering the Index granodiorite as a part of the great granodiorite batholith which is known to have been intruded into the Sierra Nevada of California and the mountains of Oregon and parts of the Cascades of Washington at the close of the Jurassic period. Within the area of the district we have no known Cretaceous formations and the age of the lava and the conglomerates lying on the margins of the district are not very well known, except that they belong to the Tertiary.

The larger part of the area and the one in which most of the copper ore deposits are located is composed of granodiorite. The question at once arises whether or not that rock was the original source of the ores and also whether they were deposited soon after its consolidation or at some later time during the Tertiary.

To the north of Index in the Monte Cristo district, Mr. Spurr has described the ores and discussed their origin. In that region the Index granodiorite is not exposed at the surface, but lies deeply buried beneath a thick covering of Tertiary sedimentary and volcanic rocks which undoubtedly are in part the equivalents of those which overlie the granodiorite in the east and southwestern parts of the Index district, and which once undoubtedly overlaid the entire district. In the Monte Cristo district, the Tertiary rocks have been fissured and filled with mineral matter composed of pyrite, chalcopyrite, and arsenopyrite, carrying values in gold and silver. These rocks are cut by dikes of tonalites which are chemically and mineralogically closely related to the Index granodiorite, but which are geologically much younger and probably had no connection with that magma. To the south, in the vicinity of Snoqualmie pass, granodiorites of the late Tertiary age are exposed at the surface and it has been suggested that the tonalite dikes in the

Monte Cristo region are small apophyses connected below with a large underlying mass of granodiorite which is part of a late Tertiary batholith. The vein fissures in that district are later than the tonalite and seem to be directly associated with it. The fissures are assumed to have been formed by those mountain making movements which resulted in the uplift of the Cascade mountains into their present position. Because of the intimate relationship of the veins to the tonalite, the ores are considered by Mr. Spurr to have been derived directly from them by circulating solutions and deposited in the fissures. These two districts are less than twelve miles apart and the intervening area contains mineral veins of similar character. The tonalite and Index granodiorite are petrographically similar, and even though the former should occur in the Index district, it would be almost impossible to distinguish it from the older granodiorite.

The Index granodiorite is cut by numerous fine grained granodiorite porphyries, much more acid than the granodiorite proper. They are in the nature of aplites and are assumed to have been intruded while the granodiorite magma was in the process of consolidation. It is possible, but not probable, that they may be the equivalent of the tonalites.

In the Index district the fissure veins cut some of the Tertiary lavas, and hence there seems to be ground for considering the fracturing and jointing to have occurred in late Tertiary time and quite possibly along with that in the Monte Cristo region.

The more prominent veins, as previously mentioned, have definite directions of strike and dip. A large number of observations taken on non-mineralized joint planes show these directions to be closely related to those of the veins and hence are assumed to have been formed along with the vein fissures during Pliocene time. These fissures are often persistent and can be traced for more than two miles. It is presumed that in the process of fracturing much of the rock adjacent to the walls of the fissures was crushed, due to friction. The width of the fissure zones are assumed to have varied from place to

place and the fissures themselves to have extended down for great depths as well as upward into rocks which have since been removed by erosion.

The source of the ores may have been the deeper parts of the Index granodiorite, but it seems more probable since the ores were deposited late in the Tertiary, that they were derived from deep seated granodiorite magmas of Tertiary age, genetically associated with the tonalite dikes at Monte Cristo and the granodiorites at Snoqualmie pass. It is also possible that the fissures may in part have been formed by the stresses in the earth's crust produced by the expansion and contraction of this underlying magma in the process of its consolidation together with pressure exerted in the uplift of the mountain mass.

The question now arises whether the ore bearing solutions were given off directly from the magma below or whether we are to assume that this had practically consolidated and cooled and that the solutions represented downward traveling meteoric waters which had come in contact with it and while passing through it under high pressure temperatures, took into solution their mineral content and upon reaching the lower portion of the fissures, traveled upwards, and, under gradually reduced pressures and temperatures, precipitated from solution their mineral content.

It is possible that both processes may have been going on. Insomuch as the time involved in the cooling of a deep seated batholith is conceived to be very long and as gases and solutions would be given from the lower portion long after the roof had consolidated, it is probable that the solutions carrying the ores were derived almost entirely from the Tertiary granodiorite.

These solutions carried silica, sulphides of copper and iron, with some lead and zinc and a small amount of gold and silver. These in general travelled along the major fissures. When the openings were clear and narrow the fissures were filled with solid ore as in the case of the Index bornite vein. Such veins

are seldom in this district more than a few inches wide and the walls are never very much altered. Where the fissures were wide and filled with crushed material the solutions had a wider area to circulate through and often extended out into the wall rock. In such cases large ore bodies or lenses were developed and the ore is found scattered in irregular bunches, some of which are of large size embedded in a gangue composed of decomposed crushed vein rock and wall rock re-cemented with silica. Such deposits are partly in the nature of replacement veins. The feldspars and amphibole of the granodiorite adjacent to the vein were altered to sericite and kaolin and the alkalis carried away in solution.

These wide ore bodies or lenses are considered to lie in the plane of the fissure and, in the intervals between the lenses, the walls of the fissures are assumed to be lying in contact. In such places the solutions would have little chance to circulate and hence the vein would be represented by a mere seam of quartz or kaolin with no ore. An examination of the veins of the district shows them to occur exactly in this way.

The primary minerals are pyrite and chalcopyrite. The secondary minerals are bornite, chalcocite, cuprite and iron oxide. The latter are assumed to have been formed by secondary enrichment. The copper-iron sulphide-chalcopyrite has been acted upon by direct oxidation, resulting in the formation of cupric and ferrous sulphates. The latter further oxidizes to ferric sulphate. In traveling downward these attack the unaltered cupriferous pyrite resulting in the formation of bornite and chalcocite, and leaving the iron in the form of an oxide. In some of the veins bornite forms the chief mineral of the ore. It often may be seen as a shell surrounding irregular masses or grains of chalcopyrite which have escaped complete alteration. This is characteristic of certain portions of the ore bodies in the Ethel Consolidated Mines just north of the mouth of Trout creek.

Considering the Index district as a whole, the ore bodies are assumed to occur in lenses lying in the plane of the fissure

with barren or nearly barren intervals between. The ore bodies will undoubtedly extend down at least one thousand feet below sea level, and will be characterized by lenses or ore chutes of varying sizes, lying in fissure veins and connected one to another by very narrow seams of ore or entirely barren seams. There is no possible means of determining where these may lie except by drifting on the veins or by the use of a diamond drill. The copper ores are certain to consist of the mineral chalcopyrite, with practically no bornite, but probably with an increasing amount of iron pyrites.

PLACERS.

The placer deposits in this district are not of commercial importance. From 1888 to 1892 many claims were located along the Skykomish river up to and beyond Galena. Considerable work was done near the mouth of Silver creek. Some gold is said to have been taken out, but no information could be obtained as to the amount. Colors can be obtained by panning at almost any point along the river but sufficient values could not be obtained to profitably mine.

The stream valley is deeply filled with glacial drift and overlying this are stream silts and gravels. It is possible that on bed rock underlying the glacial material placers might be found, but even that is not certain. If there were deposits, the expense of mining would be prohibitive because of the great depth. To the north of this district in the Sultan basin, considerable placer gold is still known to exist.

CHAPTER IV.
DETAILED DESCRIPTION OF THE MINES.

GENERAL STATEMENT.

While mapping the areal geology of this district, an effort was made to examine and study the veins and ore bodies in every mine. A number of tunnels were caved and filled with water, and hence inaccessible. There are several hundred claims which are now being held either by assessment work or patent and in addition probably as many more which have been abandoned. Eight groups have been patented. In this report only those properties which are now held will be described. In the claim map accompanying this report, nearly all of these claims have been represented. Where surveys have been made, the claims have been accurately tied into section corners. A part of the others are tied in by tape and compass survey and still others have been platted from data given by the owners. In describing each of these properties, especial attention will be given to the history, development, character of country rock and veins, and the form and distribution of the ore bodies.

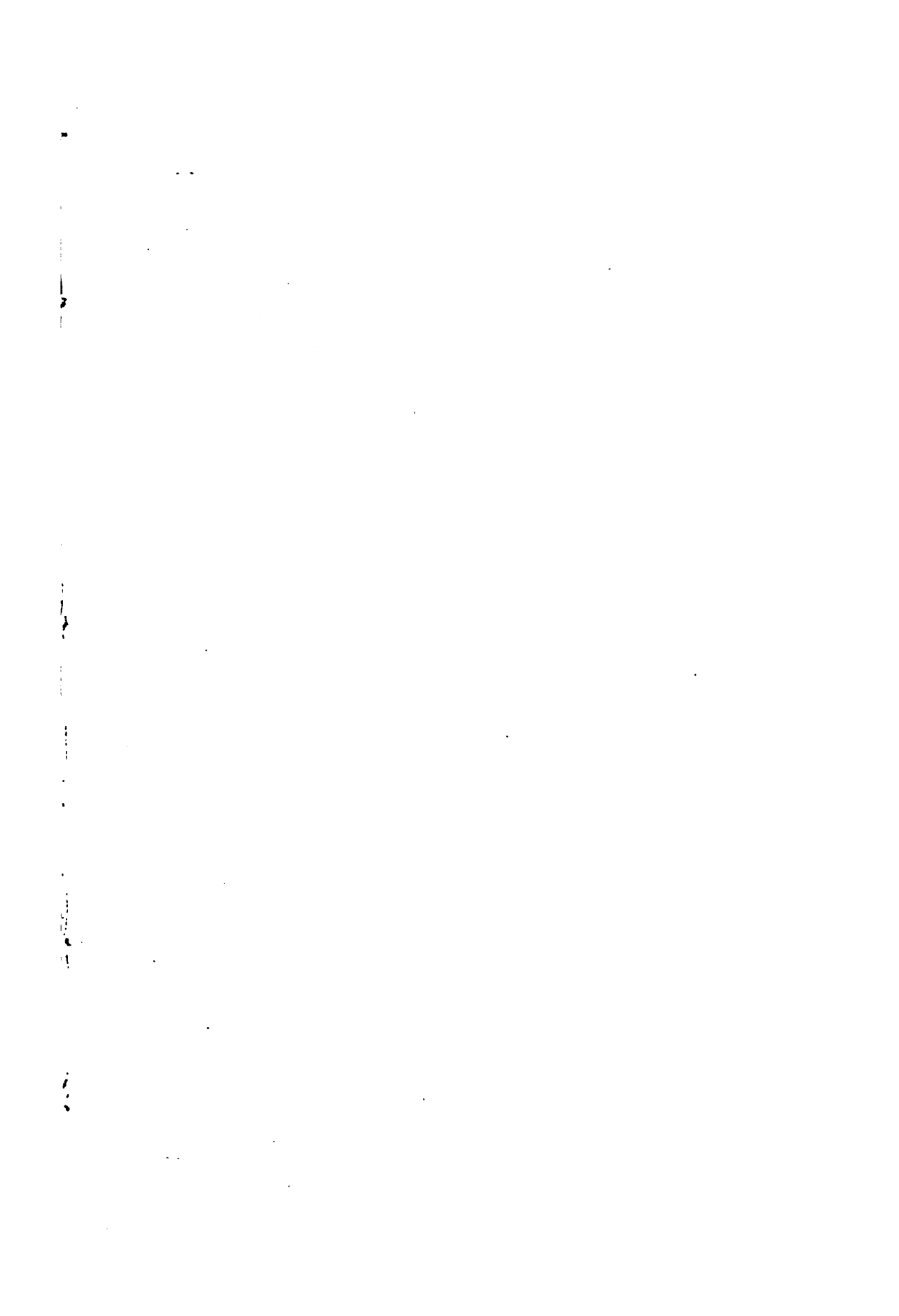
SUNSET MINE.

This property, which is one of the largest in the district, is located on Trout creek near its junction with the north fork of the Skykomish river. It is reached from Index by a surface tram road six miles in length, built along the south side of the river. The property is owned by the Sunset Mining Company and consists of thirty-six claims. The first location was made upon the Sunset Lode claim and the Black Bear claim, on June 19, 1897, by Arthur C. Egbert. It was originally incorporated as the Sunset Mining Company on July 8, 1897, by Ezra M. Egbert and Arthur C. Egbert. John McManus became secretary, E. M. Egbert, president, and Nicholas Rudebeck,

general manager. The deed was filed on August 2, 1897, by E. M. Egbert. One million shares of stock were issued at one dollar each.

The development work upon this property consists of tunnels, open cuts, trails, buildings and trams. A surface tram road has been built from the mine on Trout creek along that creek to the Skykomish river and from there to Index. A flume has been constructed from the main camp to a point about one and one-half miles up the creek where water is taken directly from Trout creek and carried to the power house for the purpose of running the electrical machinery which lights the mine and buildings. The main camp is situated on the Star claim on the east side of the creek. The underground workings are confined chiefly to the Star, Brown Bear, Black Bear, and Copper King Extension claims, although shorter tunnels and open cuts have been made on the others. The main tunnel has been driven eastward into the hill at a slight elevation above the creek, as a cross-cut from the Star claim into the Brown Bear claim. Six hundred feet from the mouth a drift has been driven on the vein both to the northwest and southeast, the former for a distance of 500 feet, and the latter for about 750 feet. About 420 feet from the intersection of the cross-cut in the right-hand drift going in, an upraise has been driven on the vein for a distance of 80 feet. From the intersection of the cross-cut and this drift, the main tunnel has been driven 475 feet farther and short drifts driven to the right and the left.

About 178 feet above the level of the lower tunnel a second short cross-cut tunnel, opening on the Black Bear claim, has been driven into the hill to the northeast for a distance of 250 feet, where the same vein was intersected as in the lower tunnel. A drift was run on the vein both to the right and left, and in the left-hand drift an upraise was driven to the surface directly on the ore body and a large amount of ore was stoped out and carried by tram to Index and shipped from there to the Tacoma smelter. On the Ravine claim about 300 feet of tunnel has been driven.





All of the underground workings are in granodiorite. On the eastern side of this property this rock comes in contact with quartzite and intrusive dike rocks. The veins have a general trend of north 78° west with a pitch of 80° to the east. In the stopes in the upper tunnel the maximum width of the vein was found to 40 feet, but the west wall has not as yet been definitely determined. Towards the surface the ore body becomes narrower as well as in depth. In the lower tunnel it varies from 2 to 16 feet and in places appears to pinch out entirely, leaving the vein simply represented by a zone of crushed and extremely altered granodiorite with a little quartz and a very thin seam of ore. The ore body proper occurs in the form of a lens with its long axis lying in the plane of the fissure and represents that portion of the fissure which is wider than the average and in which the mineral solutions deposited the larger part of the ore bearing minerals. The minerals forming the ore are mainly chalcopyrite, a small amount of bornite, with pyrite and marcasite in a gangue composed of quartz, calcite, and altered granodiorite. Some alteration of the original ore has occurred, resulting in the formation of chalcocite and cuprite. The country rock on either side of the vein proper is much altered and the biotite appears to be partially replaced by chalcopyrite and bornite.

NON PAREIL MINE.

This property consists of 32 claims located on the east side of Trout creek above and southeast of the Sunset group and about six miles from Index, from which place it is connected by a trail and surface tram road. These claims were originally located in 1898 by John Lewis. On March 6, 1903, they were incorporated by Nicholas Rudebeck, Rachel Rudebeck and George P. Rossman, as the NonPareil Consolidated Copper Company, with a capitalization of \$1,000,000 at one dollar per share.

The underground development on this property consists of 1,700 feet of tunnel, together with open cuts, trails and cabins. A tunnel has been driven into the hill on the Imperial claim for

a distance of 700 feet and about 550 feet from the mouth a cross-cut has been driven through the Imperial into the Blue Mud for the purpose of intersecting the Blue Mud lode, which occurs as a vein higher on the surface. Several smaller branch tunnels have been driven from the main tunnel. Other tunnels, part of which were inaccessible, have been driven on the other claims. The country rock on the Imperial and Blue Mud workings is granodiorite. The ores occur in fissure veins, having a general direction of about north 70° west with a vertical pitch, and consist of chalcopyrite, bornite and pyrite in a gangue composed of disintegrated and altered granodiorite partially re-cemented by quartz. The vein varies in width, ranging from one to seven feet. Three small parallel veins were intersected in the cross-cut tunnel within a distance of 200 feet from the main tunnel, but do not contain exceptionally high grade ores.

To the east on the New Lone Star, Imperial and Blue Mud extension claims, numerous open cuts and short tunnels have been made. The minerals are chalcopyrite, bornite and chalcocite.

The country rock is a part of the Gunn peak metamorphic series and is cut by a series of basic igneous dike rocks. No definite relation between the veins and country rock could be determined.

ETHEL CONSOLIDATED MINE.

Several of the claims belonging to this property were originally located in 1900. Late in August of the year 1903, the W. J. Bryan, Excelsior No. 2 and Excelsior No. 3 were located and in February, 1904, an amended location was made on the Ethel No. 1, Ethel No. 2, the Excelsior, Excelsior No. 1, Excelsior No. 2, Columbus, John D., Scotty, W. J. Bryan and the New Home claims. In December, 1905, these were incorporated as the Ethel Copper Mining Co., which later became the Ethel Consolidated Mining Company.

This property is situated in sections 34 and 35, Range 10 E., Tp. 28 N., about five and one-half miles northeast of Index on

the north side of the north fork of the Skykomish river and is reached from that town by a wagon road extending up along the river. The development work consists of a wagon road extending from the main camp to the county road just mentioned, of buildings, including bunk houses, offices, and a large concentrating plant, which has been described in a previous chapter, and approximately 3,200 feet of tunnels, upraises and shafts. Electric power is developed from Ethel creek for running the concentrating plant and lighting the mines and buildings.

There are three main tunnels. The lower and longer one is at an elevation of 1,250 feet and has been driven in on the vein for an approximate distance of 2,000 feet. About 1,000 feet from the mouth an upraise has been made on the vein for about 100 feet and much of the ore stoped out. The tunnel opens on the Edwards claim, extends through the Edwards No. 2, the New Home, and ends in the Ethel No. 2. The second tunnel opens near the level of Ethel creek at an elevation of 1,800 feet and extends south into the hill as a cross-cut for a distance of 500 feet, where it intersects the vein. At the point of intersection a drift has been driven to the west for a distance of 500 feet and an upraise made on the vein for 200 feet, where it connects with the level of the drift on the upper cross-cut tunnel. To the east of the intersection a drift has also been driven about 250 feet.

The upper cross-cut tunnel, opening at an elevation of 2,050 feet, has been driven to the south for 225 feet where it intersects the same vein, drifts have been run both to the east and to the west and the ore has been stoped out for about 100 feet above the level of this drift toward the surface. A short distance to the east from this tunnel, and about 50 feet above it in elevation, another cross-cut tunnel has been driven in about 300 feet, but the vein, apparently, has not been reached. Numerous shorter tunnels and open cuts exist on the several claims. The ore from the upper cross-cut tunnel is dropped to the level of the lower cross-cut tunnel through an ore chute and from

there, together with the ore from the latter tunnel, is transferred to the level of the main lower tunnel by a tram railway which carries it to the concentrating plant.

The country rock is granodiorite, cut by occasional narrow dikes of granodiorite porphyry of a later age. The general trend of the vein is north 75° west, with a very steep pitch to the south. It is a fracture or fissure zone in the granodiorite with the partial replacement of the ground-up country rock in the fissure with bornite, chalcopyrite, quartz, calcite, and a small amount of fluorite. Near the eastern end of the lower main tunnel the vein is only a narrow seam filled with gouge material and a small amount of bornite and iron sulphide. Farther to the west, about 1,000 feet from the mouth of the tunnel, the vein widens out and forms a part of a large ore lens which is more heavily impregnated with bornite. The ore is not evenly distributed throughout the lens but is scattered in irregular bunches, yielding a considerable amount of low grade ore. At the face of the lower cross-cut tunnel in the west drift, the same vein is again found. It is about 12 feet wide and has been partially stoped up to the level of the tunnel above. From the level of this upper tunnel, it has been stoped still further up for a distance of 100 feet. The vein is about 20 feet wide and occurs in a soft, crumbly gangue composed of decomposed granodiorite, resembling coarse arkosic sand. This is partially cemented by quartz and the mineral is almost entirely bornite with a very small amount of chalcopyrite and considerable pyrite. Calcite also occurs in places. The ore is not evenly distributed through the vein and in many places is of too low grade to be commercially mined. Many scattered bunches are, however, exceedingly rich.

KITTANNING MINE.

This mine consists of four claims known as the Cuprite, Wonder, Copper Pick, Copper Idol and Copper Bar, which were originally located in 1900, but a re-location was made in July, 1909, by Judson C. Hubbard, of Seattle. The property

is located about seven miles from Index on the north slope of the divide between Trout and Lost creeks. It is connected with Index by one trail which extends from the Sunset surface tram at the Trout creek crossing eastward along the south side of the north fork of the Skykomish river and by another trail which follows the Index-Galena wagon road to a point seven miles from the town, crosses the river and proceeds up the mountain to the mine. The development work consists of a tunnel at an elevation of 2,000 feet, driven in on the vein in a general direction north 75° east for a distance of 525 feet. The country rock is entirely granodiorite and the vein represents a zone of fracture or fissuring in this rock, filled with crushed granite much altered and partially re-cemented with quartz containing chalcopyrite, bornite, pyrite and a little chalcocite. Near the face of the tunnel the vein is five inches wide, but about 300 feet from the mouth of the tunnel it widens to two feet five inches where a short upraise has been made. Although narrow, the vein consists at this point of high grade ore which pinches on either side.

MERCHANT MINE.

This property consists of twelve claims, situated on the upper portion of Trout creek about four miles from its mouth. The majority of these claims were located in 1891, 1892, 1893 and 1896, by Andrew Merchant. In 1897 a part of them were bonded to M. E. Downs, who installed an air compressor and built a bucket tram about 2,800 feet in length from the main tunnel on the west side of Trout creek to the main camp on the creek. This property is at present owned by Robert Merchant, of Index.

The development work consists of about 1,700 feet of tunnel in the main workings just above the camp on Trout creek. In the Ore Or No Go claim there are 150 feet of tunnel; on the Fred P. claim, 500 feet; and on the Big Goat, 175 feet of tunnel. These are all connected by trails to the main horse trail on Trout creek. The country rock is granodiorite, to-

gether with metamorphic slate and quartzite. In the main tunnel just above the camp, quartzite occurs for a distance of 500 feet from the mouth. At that point it is replaced by a belt of granodiorite for a distance of 250 feet and then the metamorphic rock reappears. The main contact of the Gunn peak metamorphic formation on the south, and the granodiorite on the north, extends nearly east and west along the south side of Headquarter peak, with a nearly vertical pitch. This contact is very close to the mine workings, is distinctly intrusive, but somewhat locally disturbed by minor faulting. On the Fred P., Big Goat, and Ore Or No Go claims the country rock is entirely granodiorite. In the mine workings of the main tunnel just above the camp on Trout creek the wall rocks are hard, dark colored quartzite, having between them a fissure vein composed of crushed rock re-cemented with quartz and containing chalcopryite and pyrite, which has a general direction of N. 10° W. The vein is narrow and seldom over five feet in width and the ore is usually distributed throughout the gangue. In the south workings of this same property, downward leaching has left behind a considerable amount of micaceous hematite containing small kernels of chalcopryite and bornite scattered through it.

On the Big Goat claim the vein trends approximately north 80° west, with a nearly vertical pitch. The width varies, but averages about four feet. There is a tendency to banding which may be seen in the alternate layers of quartz with chalcopryite, pyrite and bornite. The granodiorite on either side of the vein is more or less impregnated with pyrite and chalcopryite, but not sufficient to constitute even a low grade ore. On the Fred P. claim the vein is in places 12 feet wide, similar in character to the one just mentioned, containing chalcopryite and pyrite, but not heavily mineralized. The vein in the Ore Or No Go tunnel varies in width from two to eight inches, stands vertical between granodiorite walls and contains chalcopryite and pyrite cemented by quartz.

HOMESTEAD MINE.

The eleven claims belonging to this group are situated on the west side of Trout creek about two miles above its junction with the Skykomish. These were located in 1904, 1905, 1906 and 1909, by Peter McLain and incorporated on August 3rd, 1909, as the Homestead Copper Company. Short tunnels have been opened on each and the ores, consisting of chalcopyrite and pyrite, are entirely in granodiorite.

COOPERATIVE MINE.

This is located on Howard creek about eleven miles east of Index, from which place it is reached by wagon road up the north fork of the Skykomish for a distance of eight and one-half miles. A wire rope cable and cage extends across the river to the mouth of Howard creek, and from there a good horse trail follows up the creek to its head at the lake. There are two groups of claims on this property, a lower and an upper one. The former consists of four claims; the Phoenix, Vulcan, Pennsylvania and Keystone, arranged two long and two wide on the east side of the creek about one mile above its mouth. They extend nearly east and west up the mountain side. An upper group of twelve claims is situated two and one-half miles farther up the creek. These extend about N. 75° W. and cross the creek.

These claims were first located in 1897 by Charles R. Howard and later in the same year were sold to the Cooperative Mining Syndicate. For several years following considerable work was done in developing these, but for the last six years only assessment work has been carried on.

Development work on the lower group consists of two cabins, trails and two tunnels, and several open cuts. The lower tunnel is one thousand feet above the level of the creek on the Keystone claim and has been driven in on the vein for a distance of 180 feet with a twenty-foot upraise. The lower tunnel is a cross-cut 200 feet higher for the purpose of tapping the same vein.

At the upper group several cabins have been constructed

and several hundred feet of tunnels driven. The veins are in quartzite and granodiorite and trend about N. 75° W. Near the lake a shaft has been sunk near the contact and samples collected here gave values in gold ranging from one to six dollars per ton. Chalcopyrite and bornite occur in all the veins, but pyrite predominates.

LOST CREEK MINE.

The Lost Creek property consists of several claims situated along Lost creek about nine miles east of Index. They are reached by a wagon road extending up the north fork of the Skykomish river and by a wire rope tram crossing that river to the mouth of Howard creek and thence by trail. Several claims were located here in February, 1897, and operated by the Lost Creek Mining Co. Later these changed hands several times and were finally relocated and at present are owned by E. J. Wallace and C. L. Byron of Seattle. The claims are known as the Hidden Treasure, Iron Mountain, Fraction, Mammoth, Parrott, Rudyard Kipling, Rudyard Kipling No. 1 and No. 2, East Kipling, Roosevelt and Rustic. They lie to the east of the granodiorite mass in a metamorphic belt consisting largely of quartzite which is cut by later intrusions of basic igneous rock.

On the east side of the creek at about 3,800 feet elevation, is located the Roosevelt tunnel, which is 60 feet in length and lies in quartzite. Above this is the Upper Roosevelt. The rock is badly shattered and fractured and no well defined vein could be determined, although disseminations of chalcopyrite, bornite, chalcocite, pyrite and hematite occur in the rock. Higher up on the same side of the creek is another tunnel known as the Marion, located in January, 1909. This is in quartzite and the ores are similar in character. On the west side of Lost creek at an elevation of 3,800 feet, a tunnel has been driven into the hill fifty-seven feet on a vein trending north 45° west for a distance of 85 feet. The rock is a fine grained quartzite and the ore as seen in an open cut on the surface is about eight feet wide and is characterized by quartz,





.



pretty heavily impregnated with pyrite and containing a small amount of chalcopyrite. Assays taken here gave \$4 per ton in gold and 2.8 ounces silver.

UNCLE SAM MINE.

This property is located in section 23, R. 10 E., Tp. 27 N., in the high mountain mass between the north and south forks of the Skykomish river, and more definitely, on the south slope of the divide between Lewis and Barclay creeks at an elevation of 3,200 feet. It is reached by trail from both Index and Baring, from the former a distance of four miles and the latter a distance of three miles. The property consists of four claims known as the Zenith, Baring Star, Barclay Bluffs and the Minoka, arranged two in length and two in width and extending north and south just over the ridge into the Lewis creek divide. These claims were located in May, 1897, by Mr. William Cornwall of Index. The development work consists of trails, two cabins, and about 400 feet of tunnel, three of which have been driven in on the vein.

The country rock is mainly a part of the Gunn peak metamorphic series. On the western side of the Zenith and Baring Star claims this quartzite occurs in contact with the underlying granodiorite, where the contact relations can be well studied. About 100 feet up the hill from this contact a tunnel has been driven on a ledge of mineralized matter about six feet in width lying entirely in the quartzite. This vein lies approximately parallel to the quartzite-granodiorite contact. It appears to represent a fracture in the country rock which has been the avenue for mineral bearing solutions from below to precipitate their salts. It was impossible to determine whether this fracture extended down into the granodiorite or not. The vein material consists of impregnations, in the country rock along the zone of fracturing, of micaceous hematite which contains a small amount of scattered grains of chalcopyrite and bornite. Along with these, crystals of garnet, hornblende, and orthoclase have been developed. A large amount of

pyrite also occurs in this vein. Further up the hill towards the summit of the ridge several other small tunnels have been driven on the same vein and on a parallel vein which are heavily impregnated with pyrite and a smaller amount of chalcopyrite. The latter mineral occurs sparingly disseminated throughout the entire contact zone for a distance of 1,000 feet from the granodiorite contact.

CALUMET MINE.

This property is located about six miles east of Index on the north side of Bitter creek and high up in the Gunn peak mountain mass where one of the tunnels is located at an elevation of 4,200 feet. This property is reached by the Sunset tram which extends up the north fork of the Skykomish river past the mouth of Bitter creek; from there, by a well constructed trail up the latter creek for a distance of one mile and a quarter, the trail for the last quarter mile being a switchback with a very steep grade. The main cabin is located at an elevation of 3,600 feet and the main tunnel about 500 feet higher. This property consists of four claims, which were located in 1897 by John A. Lewis, who sold it to John Rood. He built a tram from the mine to the lower camp on Bitter creek and later sold the property to W. S. Dewey, who is the present owner.

The development work consists of two tunnels and several open cuts. The lower tunnel starts at the center of the Manson claim at an elevation of 4,000 feet and has been driven on the vein into the hill along the direction north 75° east, for a distance of 500 feet. About 200 feet higher a second tunnel has been driven on the vein for a distance of 100 feet. These tunnels are difficult of access and guide ropes are used in reaching them from the main cabin. Formerly a bucket and gravity cable carried the ore from the mine to the lower camp on Bitter creek.

The country rock is entirely granodiorite and the ore bodies lie in fissure veins having a direction of north 75° east and a vertical pitch. In the upper tunnel the ore body is eight feet

wide from wall to wall and the country rock on either side is more or less impregnated with chalcopyrite. The ore consists mainly of chalcopyrite with some pyrite and a very small amount of sphalerite imbedded in a gangue of quartz, crushed and altered granite, cemented with secondary silica. In the lower tunnel the downward extension of the same vein occurs, but is much narrower and in places appears to pinch out altogether, leaving the two granite walls in contact. This ore body is apparently the lower portion of a lens or ore shute lying in the fissure vein. No records of any ore having been shipped from this mine are available.

FLORENCE-RAE MINE.

This mine is situated on the south side of the north fork of the Skykomish river, on the ridge between Trout and Bitter creeks, in section 3, Tp. 27 N., R. 10 E., and is reached by trail four miles distant from Index. There are ten claims near the river which were located by F. G. Curtis, in 1898, and six others lying two in width up near the head of Bitter creek, which were located by him in 1910. These two groups, together with the Aribel and Pearl claims, which are situated on Curry creek on the north side of the Skykomish river, in section 3, Tp. 27 N., R. 10 E., belong to the Florence-Rae Lumber, Land and Development Company.

The development work on Bitter creek consists of trails, open cuts, and 150 feet of tunnel which constitutes the main mine working and is known as the Florence-Rae tunnel. It lies at an elevation of 1,780 feet and entirely in granodiorite. The ore is mainly micaceous hematite containing scattered grains of chalcopyrite, bornite and pyrite in a gangue composed of crushed and altered granodiorite. The general direction of the tunnel is north 45° east. The ore varies in width and appears somewhat irregular in distribution. It is presumed to represent the iron which has been left behind as a result of the downward leachment of the copper sulphides. Assays taken here vary considerably, ranging from two to fifty

per cent. in iron and two ounces per ton of silver, with only a trace of gold.

THE BITTER CREEK MINE.

This property is located on Bitter creek in section 11, Tp. 27 N., R. 10 E., and consists of six claims known as the Wonder No. 1 Lode, Wonder No. 2 Lode, Standard Lode, Standard No. 1 Lode, Standard No. 2 Lode and the Maud. These were located in January, 1901, and amended locations were made in January, 1903, and surveys for patent in August, 1903. They were incorporated in the same year by B. U. Young and Nicholas Rudebeck as the Bitter Creek Mining & Milling Co. The development work consists of trails, cabins, tunnels and open cuts. The mine is located about four and one-half miles from Index and is reached from that place by the Sunset surface tram, extending up the north fork of the Skykomish as far as the mouth of Bitter creek and thence up that creek by horse trail. There are two tunnels on the Standard Lode, consisting of an upper one 600 feet long and a second one 100 feet below and about 200 feet in length, at an elevation of 3,300 feet. These have been driven in on the vein, which has a general trend of about north 66° east. The country rock is entirely granodiorite and the vein material occurs in a fissure zone filled with crushed and altered granodiorite about two feet in width and carrying bornite with some chalcopyrite and pyrite and a little micaceous hematite. Many samples of high grade ore occur, but the average ore of the vein is low grade.

INDEX BORNITE MINE.

This property is situated on Lewis creek, about two miles distant from Index, from which point it is reached by tram road and trail. During the last year the Index-Galena Lumber Company has constructed a broad-gauge track, connecting with the main line of the Great Northern Railway at Index, to a point about one mile from the mine. This road is used principally for hauling out logs, but if extended could be used for transporting ore. There are two claims, the Barry and Hillside,

which were located on May 20th, 1898, by Alec Watt, Chas. E. Cummings and York Barington. On June 2nd, 1899, these were incorporated as the Index Bornite Copper Mining Company.

The development work consists of 700 feet of tunnel, together with trails and cabins. On the center of the Barry claim there is a 70-foot shaft on the vein. On the creek a tunnel has been opened on the vein for 55 feet. A longer tunnel has also been opened which consists of a cross-cut to the vein and drifts to the right and left.

The country rock is granodiorite and the vein, which has a general direction of N. 65° E. with a pitch of 70° to the south-east, varies in width from four inches to four feet. In the shaft, it is four feet wide. In the main tunnel, where the vein is four inches wide, it is filled with pure bornite, where wider it is commonly banded with quartz and calcite and crushed granodiorite. The wall rocks are impregnated with small grains of bornite and occasionally chalcocite. Chalcopyrite occurs, but in small amounts. The walls are well defined and the ore bodies in depth will conform to the general rule applying to all in the camp—namely, lenses in the plane of the vein.

INDEX PEACOCK MINE.

There are four claims in the group which is situated on Canyon creek above the Gunn peak mine. The claims were located in 1897 and are owned by A. M. Watt, of Seattle. A tunnel has been driven on the vein for a distance of 100 feet. The vein strikes N. 65° E., is about four feet wide and composed of soft decomposed granodiorite, containing some disseminated bornite and chalcopyrite. The surrounding rock is granodiorite, but a narrow dike of fine grained diorite porphyry standing almost vertical, extends along nearly parallel to it.

GUNN PEAK MINE.

There are five claims belonging to this property which were located in July, 1897, by A. M. Watt and Chas. E. Cummings. These were incorporated on August 10, 1897, as the Gunn

Peak Copper Mining Co. The mine is situated on Canyon creek, about one-half mile east of the Index Bornite mine and is reached from Index by trail up the north fork of the Skykomish river.

There are two tunnels, one of which is 455 feet long and the other 10 feet, on Canyon creek, at an elevation of 2,500 feet. The country rock is granodiorite and the vein, which has a strike of N. 65° E. with a vertical pitch, is three feet wide and is composed of crushed granite with a very little chalcoppyrite and bornite scattered through it.

HELENA MINE.

This property is located one-half mile to the northeast of Index in the northwestern part of section 16, Tp. 27 N., R. 10 E., on the slope of the high mountain ridge forming the north wall of the Skykomish valley. It consists of two claims, the Tillicum and Tillicum Hill, located on the same ledge and having a general trend of north 45° east. These claims were located in May, 1899, by Mr. Wm. Cornwall, of Index. Development in the form of assessment work has been done continuously up to the present time. It consists of three tunnels driven into the hill on the vein which aggregate about 225 feet. The country rock is entirely composed of granodiorite and the vein, which averages about four feet in width, has a very steep dip to the south. The vein material consists of chalcoppyrite, bornite and pyrite, with a gangue of quartz, calcite, and altered granodiorite. Much of the ore is banded, showing successive layers averaging about an inch in thickness, of chalcoppyrite and pyrite alternating with narrow bands of altered and recemented granodiorite.

NORTH STAR MINE.

This property is situated about three miles northeast of Index on the north side of the north fork of the Skykomish river. It is reached by the Index-Galena wagon road for two and three-quarters miles and then by a trail extending northward for about one mile up North Star creek. There are four-

teen claims and these are owned by the North Star Mining Company. The Metropolitan, Metropolitan Extension No. 1, and the Pacific Star were located by C. E. Larson on April 7th, 1900. Three more were located by him June 7th of the same year and the remainder by S. E. Illig in January, 1903. The development consists of about 1,100 feet of tunnel. The main tunnel opens at an elevation of 2,570 feet and extends into the hill as a cross-cut for a distance of 630 feet, where it intersects the vein. This has a general trend of N. 24° E. and a pitch of 78° to the northwest. A drift has been driven to the right 150 feet and one to the left 180 feet. A second smaller tunnel has been driven in higher up the mountain.

The country rock is entirely granodiorite and the vein is of the fissure type, filled with crushed and altered wall rock and re-cemented by silica, and containing bands of bornite and chalcopyrite, varying in width from two inches to three feet. In places, as in the right-hand drift, the vein is much wider and does not contain copper ore throughout its entire width. Chalcopyrite and pyrite occur, but in subordinate amount.

INDEX INDEPENDENT MINE.

This property is located about two miles south of the town of Index in the southern part of section 30, and northern part of section 31, Tp. 27 N., R. 10 E. It lies on the south side of the Skykomish river and is reached by a suspension bridge and trail, which connect with the O. and B. Lumber Company's mill on the Great Northern Railway, one and one-half miles from Index. This property consists of five claims, viz., the Mystery, Pride of Index, Sixteen to One, Crown Jewel and the Copper Queen. These were located in 1898, amended in 1906 and a patent obtained. They are owned at present by Mr. Lot Wilbur of Snohomish, Washington.

The development work on this property is confined almost entirely to the Sixteen to One claim. This consists of three tunnels driven in southwesterly on the same vein at different elevations. The lowest, at an elevation of 1,200 feet, is 470

feet in length. The mouth of this tunnel lies at the base of a vertical granite cliff. The second tunnel, which is 125 feet higher, is reached by a switchback trail and has been driven in on the vein a distance of 170 feet. The third tunnel is 100 feet higher than the second one and has been driven in 261 feet. Several open cuts have been made on the outcroppings of the vein on the other claims, but no other underground development work has been done. A few hundred feet north of the mine are a blacksmith shop and cabin.

The country rock in this property is entirely granodiorite, which to the south and west is overlaid by metamorphic and volcanic rocks. The ores occur in distinct fissure veins, having a general strike of north 70° east, and pitching nearly vertical or steeply to the south. In the vicinity of the vein the granite is often cut by dikes of granodiorite aplite, running diagonally to the general trend of the vein. The ores are copper and consist mainly of bornite, chalcocite and chalcopryrite, with some pyrite. The fissure vein consists of small lens shaped ore bodies lying in the plane of the fissure with intervening barren areas.

BUCKEYE MINE.

This property, consisting of sixteen full sized claims and two mill sites, is located about six miles to the southeast of the town of Index on the south side of the Skykomish river and Great Northern Railway, in section 33, Tp. 7 N., R. 10 E., and is owned by the Buckeye Copper Company. The claims are all full size, extend in a direction south $29^{\circ} 26'$ east and are known as the Buckeye Nos. 1 to 16. The two mill sites are known as the Buckeye and Mountain View. These claims lie on the north flanks of the mountains forming the divide between the Skykomish and the Tolt rivers and extend over the Snohomish county line into King county. This property is reached by a trail built from a point on the Great Northern Railway about one mile west of Halford at Eagle Falls on the Skykomish. At this point the river is crossed by a footbridge

L.28N

and the trail is about one and one-half miles in length to the mine.

These claims were located in 1898 and again re-located in 1906 and surveyed for patent. The development work on this property consists of trails, bridges, bunkhouses, cookhouses, barns, numerous open cuts and three tunnels. The most extensive workings are confined to the Buckeye claims Nos. 5 and 9. Altogether approximately 1,500 feet of tunnel have been driven. The largest tunnel begins on the center lode of No. 5 claim and has been driven in southwesterly for a distance of 650 feet on the vein.

At the face of the main drift a cross-cut has been run to the left along a direction north 40° west for a distance of seventy feet where a second parallel vein is encountered. From here a drift is driven on this vein for a distance of about 500 feet in a direction south 40° west, then the main cross-cut was continued on from the point of intersection with the second vein, in a direction north 30° west, for about 150 feet. The rock is hard and costs about twenty-five dollars per foot to drive. An air compressor has been installed near the entrance to the main tunnel, but it is now out of commission. Since 1907 very little development work has been done.

All of the veins within this property are confined to the granodiorite which, to the south and west, is overlaid by a series of quartzites, slates, and volcanic rocks. The ores occur in distinct fissure veins and extend in a general direction north 40° east, pitching nearly vertical or very steeply to the southeast. The vein varies in width from a mere seam to six feet. The fissures and walls are well defined, and the ore bodies are distributed along them in irregular, lens-shaped bodies, leaving intervening areas of barren rock represented by a very narrow stringer of quartz and calcite. The ores are predominately copper and are represented by chalcopryrite, with a small amount of cuprite, bornite, and chalcocite. The large ore bodies are composed of a gangue material made up of crushed country rock which has been partly converted into

kaolin and partially cemented by silica with calcite, and contains scattered through it, irregular bunches, stringers and grains of the above mentioned copper minerals. The ore does not appear to occur in large bodies and is typically low grade. The general samples collected gave assays ranging from one to two dollars in gold with a trace of silver.

No statistics are available on the amount of ore taken out of this property. Several tons are said to have been packed out on horseback and shipped to the Tacoma smelter, but no data are available concerning the returns on this shipment. The larger part of the ore taken out lies on the dump at the mine. The estimated cost of improvements, including the underground development of the mine, is approximately \$27,000.

COPPER BELL MINE.

This property is located about five miles west of Index and is reached from Reiter, a small station on the Great Northern Railway, by a tram road less than one mile in length. The property consists of eighteen claims, which are owned by the Bunker Hill Mining & Smelting Co. The Copper Bell and South Copper Bell claims were located on January 12th, 1897, by C. H. Gray and L. W. Gray. On May 5, 1897, the Copper Bell Mining Company was organized, taking over the Copper Bell, South Copper Bell, Homestead, Jumbo, Buncombe, Warcry, Joker, Echo and Shamrock claims.

Development work consists of approximately 2,700 feet of tunnel. The main tunnel has been driven on the South Copper Bell claim through the Copper Bell and into the Jumbo claims on the main vein, a distance of about 2,400 feet. Branching off from this at numerous places are shorter tunnels. About 600 feet from the mouth, a cross-cut has been driven both to the right and to the left. To the left the main ore body was encountered and a slope sunk on the vein and an upraise made to the tunnel above, through which the larger part of the ore from this mine has been taken out. Further to the north and higher up on the Jumbo claim, two shorter tunnels have been

driven into the hill on what is probably the same vein, but a different ore lens, lying in the northeasterly extension of the same vein. The ore from these tunnels is transferred down hill by a gravity tram. A power plant has been installed on May creek and the water brought to it by flume from some distance up the creek. The power is transmitted from here to the concentrating plant and to the mine and buildings. Near the entrance to the main tunnel a large concentrating plant has been built, which has been described in the previous chapter under the heading "Treatment of Ores." In addition to this, a smelter has also been constructed at the lower camp on the Joker claim.

The country rock on this property is composed of granodiorite together with a series of metamorphic schists and quartzites. The contact between these two formations extends in a general northwesterly direction, with the granodiorite on the north and east, and the metamorphic series on the south and west, and crosses the main tunnel near the junction of the South Copper Bell and Copper Bell claims. The plane of contact is nearly vertical and, in a zone of quartzite, extending back 300 feet from the contact, are small apophyses and disconnected, irregular masses of the granodiorite scattered through it. The metamorphic rock within the tunnel is a hard, dark gray, fine to medium grained quartzite, which is locally called by the miners "diorite." The minerals comprising the ore consist mainly of chalcopyrite with occasional scattered bunches of bornite in a gangue composed of quartz and altered, crushed, re-cemented granodiorite. Near the surface much of the copper has been leached downward, leaving the iron sulphide behind in an altered form as micaceous hematite. The trend of the vein is approximately north 32° east, with a nearly vertical dip. The main ore body is a lens or ore chute, lying in the plane of the vein and has a maximum width of thirty feet, but narrows down both to the northeast and southwest as well as above and below. Much of the gangue in this lens is an extremely altered granodiorite, partially re-cemented by silica

and impregnated with chalcopyrite, pyrite and bornite. On either side of the walls, which in many cases are nothing more or less than gradations from the ore body proper into the country rock, are small scattered granules of chalcopyrite and bornite together with iron sulphide.

The ore deposits occurring in the upper workings on the Jumbo claim are much narrower, but contain the same minerals. They appear to form a part of a smaller ore lens lying in the Copper Bell vein proper. In both cases these lenses must be considered as zones in the main fissure vein in which a larger area has been ground up as the result of fracturing, and in which the ore solutions have had a better chance to circulate.

RED CROSS MINE.

This property, owned by the Red Cross Mining Company, lies in the western part of the district, two miles north of Reiter, as above and below. Much of the gangue in this lens is an at an elevation of about 3,000 feet. It is reached by trail, connecting with the tramway and horse trail of the Bunker Hill mine. There are ten claims in this group upon which several open cuts have been made. The short tunnels have been driven but no extensive work undertaken. The country rock is granodiorite and the ore occurs in fissure veins having a general trend of N. 40° E. The ore minerals are chalcopyrite, bornite and pyrite in a quartz gangue.

THE INDEX GRANITE QUARRY.

This quarry is located one-half mile west of Index, on the Great Northern Railroad and is owned by J. A. Soderberg, of Seattle. The rock, which is a part of the Index granodiorite, outcrops on a vertical cliff on the south side of the long ridge between the Skykomish river and Deer creek. It is pretty constant in petrographical character and is almost entirely free from ovoid basic secretions and joints. It has been quarried for several years and the stone has been used for paving blocks, building stone, and street curbing.

THE HALFORD GRANITE QUARRY.

About one-fifth of a mile west of Halford on the Great Northern Railway, is a steep bluff of granodiorite, jutting out at the railway track. A quarry has been opened up by the railroad company and the material is used for riprap along their roadbed. The rock is considerably weathered and contains many joints and is not adapted for building purposes.

INDEX.

	<i>Page</i>
Acknowledgments	9
Alluvial Deposits	49
Alterations of the Country Rock.....	60
Andesite Porphyry Dikes.....	44
Bitter Creek Mine.....	84
Bornite	63
Buckeye Mine	88
Calcite	64
Calumet Mine	82
Chalcocite	63
Chalcopyrite	62
Climate	28
Co-operative Mine	79
Copper Bell Mine.....	90
Corey, Prof. C. R., Assays by.....	9
Country Rock, Alterations of.....	60
Cuprite	63
Drainage	22
Ethel Consolidated Mine.....	74
Fettke, Charles R., Work of.....	9
Field-Work	9
Florence-Rae Mine	83
Fluorite	65
Forms of the Surface.....	24
Galena	63
Garnet	64
Genesis of the Ores.....	65
Geological History	51
Geology, Economic	54
Geology, General	34
Glacial Drift	48
Glaciation	25
Gold	65
Granodiorite	38
Granodiorite Aplite	43
Gunn Peak Formation.....	85
Gunn Peak Mine.....	85
Halford Granite Quarry.....	93
Helena Mine	86
Hematite	63
History of Mining.....	54
Hodges, L. K., Report by.....	14
Homestead Mine	79
Hornblende	64
Howard Arkose Formation.....	46
Index Bornite Mine.....	84
Index Granite Quarry.....	92
Index Independent Mine.....	87
Index Peacock Mine.....	85
Industries	12

	<i>Page</i>
Kaolinite	65
Kittanning Mine	76
Limonite	64
Literature	14
Lost Creek Mine	80
Malachite	63
Merchant Mine	77
Mineralogy	62
Non Parell Mine	73
North Star Mine	86
Olivine Diabase	47
Ore Bodies, Character of	58
Ore Bodies, Distribution of	57
Ore Bodies, Influence of Country Rock on	59
Ores, Treatment of	56
Physlography	21
Placers	70
Production	57
Pyrite	62
Quartz	64
Quaternary	48
Red Cross Mine	92
Russell, I. C., Reports by	15, 31
Sericite	65
Settlements	12
Silver	65
Smith, G. O., Report by	31
Sphalerite	63
Spurr, J. E., Report by	18
Strontianite	64
Structure	49
Sunset Mine	71
Talus Deposits	49
Thyng, W. S., Reports by	16, 17
Topography	21
Uncle Sam Mine	81
Vegetation	29
/ West Index Andesitic Series	44
Willis, B., Report by	31

PUBLICATIONS

OF THE

WASHINGTON GEOLOGICAL SURVEY.

Volume 1.—Annual Report for 1901. Part 1, Creation of the State Geological Survey, and An Outline of the Geology of Washington, by Henry Landes; part 2, The Metalliferous Resources of Washington, except Iron, by Henry Landes, William S. Thyng, D. A. Lyon and Milnor Roberts; part 3, The Non-Metalliferous Resources of Washington, Except Coal, by Henry Landes; part 4, The Iron Ores of Washington, by S. Shedd, and the Coal Deposits of Washington, by Henry Landes; part 5, The Water Resources of Washington, by H. G. Byers, C. A. Ruddy and R. E. Heine; part 6, Bibliography of the Literature Referring to the Geology of Washington, by Ralph Arnold. Out of print.

Volume 2.—Annual Report for 1902. Part 1, The Building and Ornamental Stones of Washington, by S. Shedd; part 2, The Coal Deposits of Washington, by Henry Landes and C. A. Ruddy. Postage 20 cents. Address, State Librarian, Olympia, Washington.

Bulletin 1.—Geology and Ore Deposits of Republic Mining District, by Joseph B. Umpleby. Bound in cloth; price, 35 cents. Address, State Librarian, Olympia, Washington.

Bulletin 2.—The Road Materials of Washington, by Henry Landes. Bound in cloth; price, 60 cents. Address, State Librarian, Olympia, Washington.

Bulletin 3.—The Coal Fields of King County, by George W. Evans. In preparation.

Bulletin 4.—The Cement Materials of Washington, by S. Shedd and A. A. Hammer. In preparation.

Bulletin 5.—Geology and Ore Deposits of the Myers Creek and Oroville-Nighthawk Districts, by Joseph B. Umpleby. Bound in cloth; price, 50 cents. Address, State Librarian, Olympia, Washington.

Bulletin 6.—Geology and Ore Deposits of the Blewett Mining District, by Charles E. Weaver. Bound in cloth; price, 50 cents. Address, State Librarian, Olympia, Washington.

Bulletin 7.—Geology and Ore Deposits of the Index Mining District, by Charles E. Weaver. Bound in cloth; price, 50 cents. Address, State Librarian, Olympia, Washington.

Bulletin 8.—Glaciation of the Puget Sound Region, by J. Harlen Bretz. In preparation.

Bulletin 9.—The Coal Fields of Kittitas County, by E. J. Saunders. In preparation.

Bulletin 10.—The Coal Fields of Pierce County. In preparation.

Bulletin 11.—The Mineral Resources of Washington, with statistics for 1911, by Henry Landes. In preparation.

Bulletin 12.—Bibliography of Washington Geology and Geography, by Gretchen O'Donnell. In preparation.

Bulletin 13.—A Preliminary Report on the Tertiary Formations of Western Washington, by Charles E. Weaver. In preparation.

(OVER)

**PUBLICATIONS OF THE U. S. GEOLOGICAL SURVEY, IN CO-
OPERATION WITH THE WASHINGTON
GEOLOGICAL SURVEY.**

(For copies of these publications address the Director, U. S. Geological Survey, Washington, D. C.)

Topographic Maps of the Following Quadrangles: Mount Vernon, Quincy, Winchester, Moses Lake, Beverly and Red Rock. Price, 5 cents each.

Water Supply Paper No. 253: Water Powers of the Cascade Range, Part I., Southern Washington.

Water Supply Paper No. —: Water Powers of the Cascade Range, Part II. In preparation.

Water Supply Paper No. —: Water Powers of the Cascade Range, Part III. In preparation.

Water Supply Paper No. 272: Results of Stream Gaging in Washington for 1909.

**PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS, IN CO-OPERATION WITH THE
WASHINGTON GEOLOGICAL SURVEY.**

(For copies of these publications address one of the members of congress from Washington.)

Reconnaissance Soil Survey of the Eastern Part of the Puget Sound Basin.

Reconnaissance Soil Survey of the Western and Southern Parts of the Puget Sound Basin. In press.

Reconnaissance Soil Survey of Southwestern Washington. In preparation.

Reconnaissance Soil Survey of the Quincy Area. In preparation.

X

2

1

1

1

1

Date Due

~~APR 23 1948~~





3 2044 102 946 480